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## **Essays in Monetary Policy Rules**

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**Thesis Submitted for Doctor of Philosophy in Economics**

**Durham University**

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**September 2013**

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Postrick Lifa Mushendami

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Postrick Lifa Mushendami

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## **ABSTRACT**

### **Essays in Monetary Policy Rules**

by Postrick Lifa Mushendami

John Taylor's (1993b) rule has revived the interest and usefulness of instrument rules in the formulation of monetary policy both among academics and practitioners. Consequently, research in this area has increased to answer among other things, which policy rule closely represent the actual monetary policy formulation of the central bank, or what is the performance of these Taylor rules compared to alternative rules.

This thesis intends to add both to the theoretical and empirical literature on monetary policy rules and structured as follows: Chapter 2 attempts to examine the implication of interest rate smoothing on the persistence of a technology and monetary policy shock. Using a closed economy model of Galí (2008), I show that interest rate smoothing (Taylor rule with lagged interest rate and backward looking Taylor rule) tend to protracts the persistence of a monetary policy shock, while it truncates the persistence of a technological innovation.

The persistence due to a monetary shock from the Taylor rule is however shorter, while that from a technology shock is longer. Thus, Taylor rule is considered superior to the Taylor rule with lagged interest rule or the backward looking Taylor rule when the economy is hit by a monetary policy shock. On the contrary, the Taylor rule with lagged interest rate and the backward looking Taylor rule is considered superior to the Taylor rule when the economy is faced with a technology shock. These results tend to suggest that a policy maker faces a trade off regarding the Taylor rule or the interest smoothing rules.

Chapter 3, attempts to rank the performance of targeting rules against instrument rules in the presence of a cost push shock. In particular, it compares the performance of the three targeting rules (namely domestic inflation targeting rule (DIT), consumer price inflation (CPI) based targeting rule, exchange rate peg (PEG) with the original Taylor rule and the Forward looking Taylor rules of Clarida, Galí and Gertler(1998), commonly known as the CGG(+1) and CGG(+4).

Using a small open economy, I show that the domestic inflation targeting rule simultaneously stabilizes the output gap and domestic inflation in the presence of a domestic technology shock and a foreign output innovation and hence superior. Among instrument rules I show that the Taylor rule is superior to its forward looking specifications CGG(+1) and CGG(+4). However, in the presence of a cost push shock the results are mixed. The domestic inflation targeting rule only stabilizes the domestic inflation, while the CGG(+1) minimizes the output gap volatilities the most. The CGG(+4) is the most inferior rule in this model and calibration, given that it maximizes the volatilities in the domestic inflation and the output gap.

Chapter 4, empirically tests whether developing countries respond to domestic demand conditions or merely responds to developments in international interest rates in their interest rate reaction function. I show that developing countries do not strictly subscribe to the Taylor principle in setting nominal interest rate. Moreover, they tend to respond to international interest rates, inflation and past interest rates. Chapter 5, concludes.

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## **Chapter 1 Introduction**

This chapter briefly introduces the New Keynesian School of thought in the new section. In the subsequent sections, I discuss the monetary transmission mechanism in the New Keynesian Model and also give a short history of monetary policy rules. There after I review the Rules vs. Discretion debate. In the last section I discuss the contribution of this thesis to literature.

The real business cycle (RBC) school of thought which is ascribed to Kydland and Prescott (1982) does not recognise the role of monetary policy in the transmission of business cycle shocks in the economy. Prescott and Kydland (1982) develop a class of model called dynamic stochastic general equilibrium (DSGE) based on microeconomic behaviour of forward looking economic agents (rational expectations) in the economic system. In this model however, prices and wages are perfectly flexible. Consequently, only real economic shocks can propagate business cycle shocks in the RBC models.

Despite for the ability to replicate the dynamics of the real economy, the assumption of the RBC models particularly that of flexible prices; leaves little space for the prognosis of macroeconomic policies. Moreover, the RBC school of thought fails to recognize the role of nominal rigidities as possible candidate for propagating shocks in the economy. The weaknesses posed by the RBC, led to the development of the New Keynesian Economics (NK) school of thought. The latter attempts to integrate the assumptions of monopolistic competition and the nominal rigidities into the RBC. The presence of nominal rigidities subsequently ensure that monetary policy have non-trivial effects on real variables. Thus, the NK school of thought has become one of the most prominent tools in the parley on monetary policy and welfare analysis.

## 1.0 The Transmission Mechanism in the New Keynesian Model

Understanding the transmission mechanism of monetary policy is critical to the discussion of monetary policy rules. Therefore, this subsection highlights the monetary transmission mechanism. In the basic closed economy New Keynesian model, the transmission mechanism operates through two main channels: the *interest rate channel* and *expectations channel*. The *interest rate channel* (inter-temporal substitution) operates in the short run when prices are sticky. Accordingly, a rise in the nominal interest rate translates into higher real interest rate which subsequently influence demand decisions of the private sector.

For instance, an increase in the real interest rate causes households to buy more bonds, leading to a decline in consumption in the current period. Similarly, the higher real interest rate dissuades corporate bodies from investing more given that only fewer projects can be profitable. The two factors tend to reinforce each other and subsequently lower the aggregate demand. The fall in demand dampens inflationary pressures through the aggregate supply (Phillips curve).

*The expectations channel.* Monetary policy affects the expectations of economic agents given the fact that the model is forward looking. For instance, when inflation is below the target, economic agents anticipate a relaxation of the monetary policy stance and hence increase the expectation of future inflation. This in turn affects the pricing or wage setting behaviour (Svensson, 1999). Moreover, because of rational expectations, agents might not react to temporal shocks in the economy which might have no second round effects.

In an open economy, there is an *exchange rate channel* in addition to the *interest rate* and *expectations channels*. The exchange rate is affected by changes in domestic nominal income relative to foreign nominal income as well as the expected future exchange rate. The latter operates through the interest parity condition. When prices are sticky, changes in the nominal exchange rate affects the real exchange rate.

Thus, the real exchange rate in turn affects the demand for domestic as well as foreign goods via the relative prices. This in turn adds to the interest rate channel. For instance, a rise in the domestic nominal interest rate above the foreign interest rate requires a depreciation of the domestic currency for equilibrium in the foreign exchange to hold (uncovered interest parity condition). Other things being held equal, a rise in the domestic interest rates increases the attractiveness of domestic debt instruments and hence causes an appreciation of the domestic currency. That is, if nominal prices are slow to adjust, domestically produced goods become more expensive than their foreign counterparts. Consequently, net exports, employment, domestic output and inflation falls causing a depreciation of the nominal exchange rate.

On the other hand, an appreciation of the exchange rate might cause an increase in demand and subsequently lead to increase in inflation. The latter effect might be realised in case where domestic agents hold substantial amount of foreign denominated debts. i.e. An appreciation may lead to an increase in income of domestic households on account of reduced loan repayments, which might also lead to an increase in domestic demand and inflation. Moreover, the exchange rate (appreciation or depreciation) affects the consumer price inflation (CPI), through import prices. The exchange rate may affect domestic prices through input prices, which subsequently affect the nominal wages and the CPI. A number of studies which examines the effects of monetary policy on real effects include King and Wolman (1996), Rotemberg & Woodford (1997, 1999), Clarida, Galí and Gertler (1999), Erceg, Henderson and Levin (2000), Fuhrer (2000) and Goodfriend and King (1997, 2001).

## **1.1 Monetary Policy Rules**

Monetary policy rules have a long history. Adam Smith considered being the father of economics contends that “a well-regulated paper-money” could have very significant advantages in enhancing economic growth and stability in contrast to a pure commodity standard.

At the beginning of the 19th century, Henry Thornton and later David Ricardo similarly put emphasis on the importance of monetary policy rules following the monetary induced crisis which was ascribed to the Napoleon Wars. In the 20<sup>th</sup> century Knut Wicksell advanced the need for monetary policy rules as a way to avoid monetary expansion which brought the hyperinflation that followed the First World War. Milton Friedman after studying the monetary policy mistakes of the Great Depression proposed a constant rule to avoid the re-occurrence of a similar mistake. In the 1980's financial institutions developed substitutes for money which brought instability of the demand for money. In this vein, Svensson (1999a), contends that in the short run money and inflation are uncorrelated, despite for the existence of a stable long run relation between the two variables.

The extant literature in monetary economics on monetary policy often classifies monetary policy rules into two main strands: instrument rules and targeting rules. Instrument rule refer to a function which prescribes setting the instrument of the central bank in response to changes in the observed predetermined or forward-looking macroeconomic variables or both. They are simple feedback rules which tie the policy instrument to forecasted variables if they deviate from a set target. Examples of instrument rules includes among others: Taylor Rule, McCallum Rules, Open Economy Rules and Forward looking Rules. I briefly discuss these rules in the next section.

### Taylor rule

Taylor's (1993b) famous Taylor rules captures the most recent research on monetary policy rules in which the instrument rate responds to inflation and output gap according to:

$$r_t = \pi_t + 0.5y + 0.5(\pi_t - 2) + 2; \quad (1.1)$$

where  $\pi_t$  stands for the rate of inflation during the previous four quarters  $y_t$  is the percentage deviations of the real GDP from the growth trend,  $r_t$  is the short-run nominal interest rate. The inflation target and the equilibrium real interest rate are equal to 2. The rule recommends that the short-term interest rate be lowered (raised) when the output gap or inflation is below (above) a specified target. Taylor (1993b) finds the rule fitting the monetary policy of the Federal Reserve Bank (FED) for the period 1987 to 1992. Mankiw (2001) suggests that central banks should target a positive inflation rate in order to avoid liquidity traps and also because inflation greases the wheels of the labour market, as it ensures that the labour market work better.

### McCallum Rule

McCallum (1988) proposed a rule which adjusts the monetary base growth rate up or down when the nominal GDP growth is below or above a chosen target value as follows:

$$\Delta b_t = \Delta x^* - \Delta v_t^\alpha + 0.5(\Delta x^* - \Delta x_{t-1}); \quad (1.2)$$

where  $\Delta b_t$  denotes the change in the log of the adjusted monetary base,  $\Delta x_t$  is the rate of growth of nominal GDP,  $\Delta x^*$  is the desired or targeted growth of nominal GDP, specified as  $\pi^* + \Delta y^*$ , (targeted inflation plus the expected long run average growth rate of the real output). Where  $\pi^*$  where is the targeted inflation and  $\Delta y^*$  is the long run average rate of growth of real GDP. For the U.S. economy McCallum assumed  $\Delta x^*$  of 5 percent, calculated as the sum of targeted inflation rate of 2 percent and the average rate of real GDP of 3 percent per year.  $\Delta v_t^\alpha$ <sup>1</sup> is the average growth of base velocity over the previous 16 quarters. Given that changes in technology and regulation affects the growth of the base velocity from year to year, a problem that undermined Friedman's rule;  $\Delta v_t^\alpha$  is instead an average of the past four years intended to forecast the average growth rate of the velocity in the foreseeable future rather than reflect current cyclical conditions represented by the term  $\Delta x^* - \Delta x_{t-1}$ .

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<sup>1</sup>  $v_t = x_t - b_t$  is the log base velocity of demand for the monetary base.



The growth in the monetary base must thus be equal to the targeted growth of the nominal GDP, thus there is a comparative feedback to the growth rate of the monetary base coming from the gap between the nominal GDP and its targeted growth rate. If the relationship between the monetary base and the nominal GDP change due to financial innovations for instance, the growth rate of the monetary base must be accordingly adjusted. Other implication of the McCallum rule is that the monetary policy rule should use information which is explicitly available when the instrument is set. Besides, it must take account of the fact that data for variables such as GDP is only available with a lag. Thus, the policy rule should use nominal GDP from the previous quarter; alternatively it should use forecasts of the predetermined variables.

Empirically, the Taylor rule and the McCallum rules have coincided over many periods in the past. They however produced divergent results in two cases (UK using the data for the late 1980s and Japan using data between 1972-1998). In case of the former, the Taylor rule pointed to an easing in policy, while McCallum rule prescribed a tighter policy. In case of Japan, McCallum (1993) provides evidence that the policy rules that used monetary base as a variable would have identified that the policy was too tight after the 1991. He thus suggests that targeting the monetary base would have been a better monetary policy for Japan then.

McCallum (1999) however states that the Taylor rule is more popular because it captures the tendency of most central banks that conducts monetary policies by changing interest rates rather than the growth rate of the adjusted monetary base (currency plus bank reserves). The weakness of the Taylor rule nevertheless is that it requires estimating the output gap which is difficult. On the contrary the McCallum rule does not require the estimation of the output gap. Debelle (1999), evaluates the performance of different monetary policy rules in terms of reducing the volatilities of inflation and output. He argues that the Taylor rule outperforms other monetary policy rules such the inflation only rule, price level rule, nominal income level rule, nominal income growth rule.

Hamalainen (2004) presents a comprehensive review of the Taylor rule when contrasted to the behaviour of the FED and observes the following. He first notes that, the Taylor rule in its generic form does not capture the effect of the exchange rate. Second, there is no agreement regarding interest rate smoothing, backward-looking and forward-looking expectations in the Taylor rule. Third, the weights on the inflation and output can be estimated directly or be inferred through minimising the loss function where the fluctuations between the output and inflation are explicitly expressed. Thus, there have been several attempts to achieve an improved Taylor rule by inter-alia, including forward-looking variables, exchange rate or using forecast values of the output and inflation.

### Open-Economy Rules

Svensson (1998) claims that in the Taylor rule, the instruments are restricted to respond only to the deviations between the variables and their target level and lagged instrument. Hence, in its standard form the Taylor rule is backward looking and is meant for a closed economy of the USA. Ball (1998) and Svensson (1998b) also argue that in an open economy, Taylor rules are sub-optimal given that they ignore the role of the exchange rate which is very important in the transmission mechanism of shocks. Thus, Ball (1999b), recommends the inclusion of the exchange rate in the policy design to take into account the open economy. Moreover, Debelle (1999) suggests that by including the exchange rate, the central bank can reduce the variability of both the output and inflation. Adding the exchange rate, the Taylor rule can be expressed as:

$$i_t = i_t^* + \phi_\pi (\pi_t - \pi^*) + \phi_y (y_t - y^*) + \phi_e e_t, \quad (1.3)$$

where  $\phi_\pi$ ,  $\phi_y$  and  $\phi_e$  are the coefficients on inflation, output and the exchange rate respectively. Ball (1999b) suggests two changes to the optimal rule in an open economy. (1) The policy instrument becomes a weighted average of the interest rate and the exchange rate which is called the Monetary Condition Index (MCI). (2) Given that inflation targeting in open economies may lead to a high erraticism of the exchange rate and output, those fluctuations can be evaded by targeting the long run inflation.

Therefore, the second change consists of substituting the inflation with the long inflation to filters out the effects of the exchange rate volatilities. Thus the main difference between the closed economy and the open economy resides on two aspects (the index and the long run inflation). Canada, New Zealand, and Sweden which follows the Canadian monetary policy closely follow the MCI approach. The rationale for using a (MCI) is that it measures the overall stance of policy, including the incentives through both the real interest rate and the exchange rate. According to Ball (1998) the optimal policy for a central bank which follows the MCI is as follows:

$$wr_t = (1-w)e_t = \alpha \tilde{y}_t + b(\pi_t + \gamma e_{t-1}), \quad (1.4)$$

$r_t$  is the real interest rate,  $\tilde{y}_t$  is the log of real output,  $\alpha$ ,  $b$  are positive constants to be determined, and  $\gamma$  is a positive coefficient,  $w$  is the weight on the real interest rate ( $0 < w < 1$ ) and  $wr_t + (1-w)e_t$  is the monetary conditions index (MCI).  $\gamma e_{t-1}$  is interpreted as a long-run forecast of inflation, assuming that output is kept at its natural level. In the closed economy this is represented by the current inflation, in the open economy however current inflation changes due to the exchange rate. Ball (2000) suggested that theoretically (1.3) and (1.4) are identical; the only difference is the choice of the policy instrument (i.e. interest rate or an MCI). This choice depends on the degree of flexibility available to the policy makers.

Longworth and O'Reilly (2000), contend that Ball's results depend on the assumptions that shocks are white noise and uncorrelated across equations, which do not hold for a small open economy. Accordingly, they extend Ball's rule to include new exogenous explanatory variable  $x$  due to the fact that foreign output and commodity prices affects both the exchange rate as well as the demand. Hence, the optimal policy rule becomes:

$$wr_t = (1-w)e_t = \alpha y_t + b(\pi_t + \gamma e_{t-1}) + cX_t, \quad (1.5)$$

where all the variables are measured as deviations from their average values,  $wr_t + (1-w)e_t$  represents the monetary conditions index (MCI),  $y_t$  is the output gap,

$(\pi + fe_{t-1})$  is the core inflation, (i.e. inflation measure which excludes the direct but temporary effects of the exchange rate movements).  $c$  is a constant vector that depends on the parameters of the model,  $X_t$  is the exchange rate. The instrument responds to changes in  $X_t$  given that it affects the future path of output and inflation. According to Srour (1999) for instance, an autonomous rise in the exchange rate needs constant monetary conditions, while a rise caused by an increase in real commodity prices necessitate tighter monetary conditions. Bernanke and Gertler (2001) dispute that policies which include asset prices such as the exchange rate increase the aggregate volatility of the policy instrument and thus do not improve macroeconomic performance.

### Forward looking Rules

The standard Taylor rule is a backward-looking rule in form, while inflation targeting is a forward-looking rule. Thus, Svensson (2000), states that given that inflation reacts with long and variable lags, the central bank has to adopt a forward-looking perspective by attempting to control inflation a few years ahead. The magnitude of forward lookingness is supposed to be determined by the transmission lag. This forward-looking perspective of monetary policy is not new. For instance Keynes observed in his 1923 Tract on Monetary Reform that, "if we wait until a price movement is actually a foot before applying remedial measures, we may be too late".

Therefore a policy rule is considered forward looking if it includes explicit forecast values of output and inflation. According to Debelle (1999) a policy rule which take lags may reduce the variability of both inflation and output. Therefore the commonly used Taylor rule uses estimated (forecasted) values of inflation rather than the current inflation. Collectively these rules are called inflation forecasting based (IFB) rules. In this case, the reaction function involves adjusting interest rates to the expected future deviations of inflation from its target level. The rules may include interest rate smoothing or contemporaneous output gap (Canada for example) or other terms. These kinds of rules are used by the central Bank of Canada. Batini and Haldane (1999) examined the IFB

rules for the UK. They conclude that those rules are efficient in terms of minimizing the inflation and output variability compared to the standard Taylor rule.

Similarly, Longworth and O'Reilly (2000) contend that forward-looking rules performs better than Taylor-type rules in terms of average stability (reducing the variability of the interest rate, inflation and output). Their argument was based on a study that compared the results from non-linear rules (rules which do not respond until inflation falls outside the bands), Taylor-type rules which respond both to deviations of inflation from its targeted level and to deviations of output from its potential using current or lagged information and the IFB rules. Moreover, to obtain more information an output gap term was also included to the forward-looking rule, to bring it much closer to Taylor Rule.

Furthermore, Srouf (2003) observes that IFB rules are as efficient as the optimal rules and also easier to monitor than other rules. Other types of instrument rules include several interest rate rules studied by Henderson and McKibbin (1993a, 1993b) as well as the activist monetary base policy rules of Meltzer (1987). Despite that there are many instrument rules, in this thesis I compare the performance of the various formulations of Taylor rules. This due to the superior performance of Taylor type rules compared to other policy rules and their wide usage by most central banks in the world (McCallum 1999, Debelle 1999).

### Targeting Rules

Svensson (1997, 1999 and 2003) defines Targeting rules as “General targeting rules essentially specifying the operational objectives for monetary policy and specific targeting rules essentially specifying the operational Euler conditions for monetary policy. In particular, an optimal targeting rule expresses the equality of the marginal rates of transformation and the marginal rates of substitution between the target variables in an operational way”. Thus, the term targeting rules links the general target rule to the specification of the objective function of the central bank whilst specific target rule is linked to the setting of the policy instrument to achieve a specific target which is not essentially optimal.

Examples of targeting rules are inflation targeting, money-growth targeting, nominal GDP targeting and price-level targeting. Specific targets can be the exchange rate, nominal income or inflation. Svensson(1997), Rudebusch and Svensson (1999) however suggest that it is better for instruments to respond to both the current inflation and the output gap, given that they both determine future inflation. The section which follows discusses the rules vs. discretionary monetary policy in the context of instrument and targeting rules.

## **1.2 Rules vs. Discretionary Monetary Policy**

The discretion versus rules debate is at the centre of monetary economics. In a rule based monetary policy, the monetary authority commits to a specified path of the instrument variable. Under discretion monetary policy, the monetary authority re-optimises the choice of the instrumental variables from time to time. Bernanke and Mishkin (1997) suggest that classifying targeting rules as “constrained discretion” serves as a middle ground between targeting and instrument rules. Taylor (2000) warns against mechanical application of monetary policy rules without judgement. Similarly, McCallum (2004) stresses that central bankers should be flexible decision makers who allow deviations from the rule, as long as such deviations are rational and explained to the general public.

McCallum and Nelson (2000) disputes that no central bank has ever announced and committed itself to a targeting rule, a point Svensson (2003) contend. Moreover, Svensson (2004) claims that only targeting rules involve discretion while instrument rules do not provide any judgement. Thus, he argues that a firm commitment to instrument rules is not attractive; rather instrument rules should serve as guidelines for conducting monetary policy. In a discretionary monetary policy, the central bank identifies the shock as well as its effect on the economy and subsequently chooses a policy action to follow based on its judgement. Likewise, in instances where a rule based policy does not provide a good guide for the economy or where the relationship between variables does

not follow a well-established pattern, discretionary monetary policy is unavoidable.

On the contrary, Taylor (2000) suggests that an inflation target is not sufficient given that it requires an instrument rule to achieve the set target. Taylor (2000, p.11) uses the analogy of sailing a boat to describe an instrument rule and inflation targeting: “Inflation targeting is like the destination for a sail boat. A policy rule is how to sail the boat to get to the destination: for this you need to describe the angle of the attack, the sail trim, the contingency for the wind change, and so on<sup>2</sup>”. The general consensus is that, if the performance of the economy is measured in terms of the stability of the output and inflation, then monetary policy rules are preferred over discretion. The other consensus is for policymakers to shun the time-inconsistency problem when following rule based monetary policy. Therefore, policymakers should communicate their actions to the public to enhance accountability and credibility. In this way uncertainty is reduced given that households can predict the actions of the central bank.

Friedman (2000) lists the following advantages of rule based policies: First, unlike a discretionary policy the central bank cannot exploit the inflation-output trade-off which might cause a rise in inflation in the future and subsequently lead to unemployment in case when an aggressive disinflation strategy is taken. Therefore, policymakers should commit to a fixed monetary policy rule. Second, the social welfare may increase when the central bank adopts and commit to a rule which can be predicted by private agents. This can be due to the fact that the uncertainty in investment and consumption is reduced. Third, policy rules may decrease the risk premium in the financial markets and thus increase the predictability of returns in the short run. Proponents of rule based policy assume that policymakers have a thorough knowledge of the operations of the economy and the relationship among variables. Furthermore, they assume that the relationship between the variables is constant over time.

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<sup>2</sup> Taylor (2000, p.11).

### 1.3 Thesis objectives and contribution

This thesis makes a contribution to the theoretical and empirical literature on monetary policy rules. Specifically, it raises the following three questions: Firstly, what are the implications of interest smoothing on the persistence and transmission of a monetary policy and technology shock? Secondly, which monetary policy rule (targeting or instrument rule) performs better in light of a cost push shock? Thirdly, do developing economies react to international interest rate(s) when setting their interest rates?

The objective of my thesis is to respond to the three questions above. Its trajectory is organised along five chapters. Chapter two addresses the first question posed in the thesis. It draws mainly from the research and findings of Taylor (1993), Amato and Laubach (1999), Mishikin (1999), Srouf (2001), Rudebusch (2002), Woodford (2003) and Castelnuovo (2005). All the above work bears a homogenous quality with Amato and Laubach providing an exception. Whilst the other research empirically examine whether central banks undertake interest rate smoothing or not, Amato and Laubach (1999) serve as a precursor in incorporating interest rate smoothing in a New Keynesian Closed Economy Model. They find interest rate smoothing to increase the persistence of a demand shock (government expenditure shock), on inflation, output gap and nominal interest rate.

In chapter two I examine the implications of interest rate smoothing on the persistence of a monetary and technology shock in a New Keynesian Closed Economy Model of Galí (2008). I contribute to the model by including two additional monetary policy rules in particular the Taylor rule with lagged interest rate and the backward looking Taylor rule. I model interest rate smoothing by including lagged interest rate in the two policy rules. Gerlach and Tillmann (2010) contend that monetary policy is viewed as effective when its persistence on inflation is short lived in contrast to long live persistence. The intuition is that the central bank is able to achieve its objective of fighting inflation in a very short time when persistence is short lived. On the contrary when the persistence of inflation is long lived, the central bank is only able to achieve its objectives after a long period of time and



thus considered as ineffective (Gerlach and Tillmann, 2010). Thus the significance of the persistence of shocks on inflation and output cannot be overemphasized.

I show that interest rate smoothing (Taylor with lagged interest rate or the backward looking Taylor rule) elongates the persistence of a monetary shock on inflation and output gap, while it truncates the persistence of a technology shock of the same variables, when compared to the Taylor rule. Thus, the Taylor rule is considered superior to the Taylor rule with lagged interest rule or the backward looking Taylor rule when the economy is hit by a monetary policy shock. On the contrary, the Taylor rule with lagged interest rate and the backward looking Taylor rule is considered superior to the Taylor rule when the economy is faced with a technology shock. These results tend to suggest that a policy maker faces a trade off.

Chapter three responds to the second question. The chapter draws from two different strands on monetary policy rules in an open economy. The first strand comprises of: Aoki (2001), Clarida et al. (2001) and Galí and Monacelli (2002) and Galí (2008), who recommend monetary policy to stabilise the domestic price inflation and let the exchange rate float. The second strand includes: Smelts and Wouters (2002), Sutherland (2002), Benigno and Benigno (2003) and De Paoli (2009) who argues that optimal monetary policy in an open economy should take the volatility of exchange rate into account. The common link of the extant literature is their use of a welfare based method of evaluation. In a theoretical situation it is easy to include a cost push shock and evaluate the optimal policy. In practice however, the welfare maximising strategy is difficult and complicated. Therefore the optimal policy may involve responding to variables which cannot be measured or observed. In this case, the monetary authority might find it impractical to follow an optimal policy.

Therefore, it may be helpful to analyse the performance of simple targeting and instrument rules using the impulse response functions and volatilities. This is the approach embraced in this chapter and marks a point of departure from similar studies. The chapter builds on Galí (2008) who use a small open economy and compare the performance of the DIT, CIT, Taylor rule and the Peg. He concludes that the DIT rule can

simultaneously stabilise the output gap and domestic inflation in the presence of a technology shock. I make the following contributions and extensions to the model. Firstly, I include a cost push shock and a foreign output shock. Secondly, I include the DIT, CIT, of Galí and Monacelli (2002) and thirdly, I incorporate Forward looking Taylor rules of Clarida, Galí and Gertler (1998), commonly known as the CGG(+1) and the CGG(+4) rules. To date, no other study exists which incorporates the Forward looking Taylor rules into the small open economy, characterised by a cost push shock. I show that the DIT continues to stabilise the output gap and domestic inflation in the presence of a technology and foreign output shocks and hence superior to other rules. Moreover, I show that the Taylor rule is superior to the CGG(+1) and the CGG(+4).

However, the results produced have the tendency to be mixed when a cost push shock hits the economy. In this case, the DIT only stabilises the domestic inflation, while the CGG(+1) minimizes the volatilities of the output gap the most. The CGG(+4) is the most inferior policy rule, because it worsens the wealth of the consumer. Thus these results suggest that the central bank faces a policy dilemma as to which policy rules is superior in terms of stabilising both the output gap and domestic inflation in the event of a cost push shock. This dilemma is caused by the fact that in practise policy makers cannot alter policy rules with each shock hitting the economy.

Chapter four examines the third question by empirically testing whether developing countries respond to international interest rates in setting their policy rates or observe the Taylor rule. It draws mainly from Clarida, Galí and Gertler (1998), Calvo and Reinhart (2001 and 2002), Filosa (2001), Corbo (2002), Frankel et al. (2004) and Boamah (2012). These studies show that emerging market economies respond to other factors such as the exchange rate in setting their interest rate policy in addition to inflation. This is attributed to the fear of floating which might be caused by among other things: lack of credibility, exchange rate path through to inflation and foreign currency liabilities which may prevent developing countries from undertaking independent monetary policies. Frankel et al (2004) argues for example that even developing countries with fully flexible exchange rate tend to import price stability from developed countries similar to countries whose exchange rates are fixed.

A related characteristic of the extant literature is the propensity of most researchers focusing on either individual country or regional experiences, apart from Filosa (2001) and Frankel et al. (2004). This chapter studies the interest rate setting behaviour of central banks in three regions (Latin America, East Asia and Southern Africa, using data from 1999 to 2012 and hence its first contribution to literature. It differs from Filosa, (2001) in that he examines the interest setting of developing countries across two regions (East Asia and Latin America). Also other variances stems from the number and selection of countries and the research question at hand.

The chapter is also different from Frankel et al. (2004) who test how the exchange rate (independent, pegs or managed floats) affects the transmission of international interest rates to local interests. While they use data on a large number of developing and industrialised countries during the 1970 to 1999, in this chapter I consider eight developing countries, during the period 1999 to 2012. In particular, this chapter builds on Forward looking Taylor rule proposed by Clarida, Galí and Gertler (1998).

As the second and third contributions, I make two modifications to their rule: First I replace the output with the expected output as in Javanovic and Petreski (2012). Second I include the U.S. interest rate, to test the claim by Frankel et al (2004) that interest rates in developing countries with flexible exchange rates might sometimes be more responsive to the international interest rates in addition to domestic economic considerations. The chapter is estimated using the GMM methodology as in Clarida, Galí and Gertler (1998). I show that developing countries respond to past interest rates, expected inflation and U.S. interest rates when setting their interest rates. The coefficient of the expected inflation is however less than unity in all countries. These results are similar to Corbo's for Latin American countries. A distinct finding of this chapter is the significance of the U.S. interest rate in the monetary policy rules of most countries, when they are inflation targeters. Chapter 5 concludes.

## **Chapter 2 Interest Rate Smoothing and Persistence**

### **2.0 Introduction and Literature Review**

The Taylor (1993) rule has re-kindled the attention of researchers involved in monetary policy. Its success has been that by linking the inflation rate and the measure of the output gap to the monetary policy rule; it provided a good description of the monetary policies practiced by many central banks in the Euro area (Castelnuovo, 2005). Nevertheless the Taylor rule of 1993 is a purely contemporaneous rule, i.e. it makes the current nominal interest a linear function of the current output gap and current rate of inflation only.

However, many econometricians find that the fit of the Taylor rule improves when lagged interest rate is added into the objective function of the central bank (Castelnuovo, 2005). The practice of including lagged values of interest rate among the regressors of the monetary policy rule is often referred to as interest rate smoothing or monetary policy inertia. Such kind of smoothing means that changes in the targeted interest rate are dampened (Amato and Laubach, 1999). Interest rate smoothing is relatively broad and includes the actions of the central bank to change the policy interest rates in small steps (Goodhart, 1997) as well as moving the interest rates in small steps without reversing the direction quickly (Amato and Laubach, 1999).

Amato and Laubach (1999) list other kinds of interest rate smoothing such as seasonal smoothing, day to day smoothing and event smoothing. Seasonal smoothing is defined as the efforts of the central bank to reduce calendar patterns in the interest rate. Event smoothing is when the central bank provides liquidity to the market to avoid large swings in the interest rate. This kind of smoothing may be considered during the occurrence of a crisis which might put pressure on interest rate.

Day-to-day smoothing on the other hand means that the average level of the interest rate over a period of days is close to the target desired by the central bank. However, this chapter uses the earlier definition of interest rate smoothing (i.e. inclusion of lagged interest rate into the monetary policy rule). Many researchers agree that most central banks engage in interest rate smoothing. For instance Amato and Laubach (1999) argue that there is ample evidence which points that the Federal Reserve Bank (Fed) undertook interest rate smoothing in the past. Srouf (2001) provides evidence that the Bank of Canada reaction function shows the propensity to have been smoothed. Similarly, Castelnuovo (2005) found that the Taylor rules for the Euro area tend to show interest rate smoothing. Nevertheless, Rudebusch (2002) argues that at quarterly frequencies interest rate smoothing is just an illusion.

Moreover, he argues that if partial adjustment strategy is accorded high importance in the setting of the interest rate, rational agents would be capable of predicting the future values of the policy rate with a relatively high degree of precision. However, he states that results obtained from the standard term structure regressions shows that the policy rate is unpredictable over one period. There are several reasons which justify central banks' preference to smooth the interest rates, which I discuss in the rest of this section.

(1) Stability. Woodford (2003) states that “central banks seek to smooth interest rates, in the sense that they seek to minimize the volatility in the interest rates, in addition to other objectives”. This is due to the fact that large swings in interest rate can cause large fluctuations in the cash flow of individual corporate institutions, financial intermediaries and government with large debts which may destabilize the financial and exchange markets.

(2) Commitment and Credibility. Mishkin (1999) argues that the credibility problem may preclude the monetary authority from reversing the policy rate too frequently, as sudden large reversals in policy may cause the public to lose confidence in the central bank. Furthermore, given that private agents are forward looking, small movements in the

interest rate which persist over time may be more effective than large and transitory changes (Amato and Laubach, 1999). Therefore, policy makers may be effective if they commit to a certain course of action over an extended period (Srouf, 2001). For example, suppose that a firm which finances its investment by borrowing short term expects an increase in the interest rate which is short lived. The firm will borrow and roll over its debt at a lower interest rate. Similarly, if the firm borrows long term, it will do so at unchanged long term interest rates. The latter is based on the fact that when financial markets are efficient, a temporary increase in the short-term interest rates will have little effect on long term interest rates. In both scenarios, the borrowing costs of the firm will remain unchanged due to short lived persistence and hence monetary policy will be less effective.

On the contrary, if the firm expects the increase in the short-term rates to persist over a long time, it might cancel or scale down the investment project. Suppose the firm intends to finance the project with a short-term loan. In this case, it will expect to continue paying the loan for some time into the future and thus roll over the debt at higher interest rate. Similarly in the case of long-term financing, the firm will pay higher long term interest rates. The latter stems from the expectation theory of the yield curve which states that an increase in the short term interest rate which is expected to persist will have bigger impact on the long term interest rates than an increase which is expected not to persist. Thus, long lived persistence in the latter case increases the effectiveness of monetary policy.

(3) Uncertainty faced by policy makers about the economy and the effect of monetary actions. Sack (2000) argues that the central bank might engage in interest rate smoothing; when there is uncertainty about the parameters of the economy or when the structure of the economy is changing. Similarly, Orphanides (2003) argues that monetary authorities often respond gradually to shocks taking into account that they might contain noise. Furthermore, Favero and Milani (2001) and Castelnuovo and Surico (2004) suggests that model uncertainty has been an important consideration for the Federal Reserve Bank.

Therefore, it is advisable for a central bank to move the policy rate gradually until the uncertainty subside.

The implication of persistence on inflation and output is however different. Gerlach and Tillmann (2010) for instance contends that monetary policy is viewed as effective when its persistence on inflation is short lived in contrast to long lived persistence. The intuition is that the central bank is able to achieve its objective of fighting inflation in a very short time when persistence is short lived. On the contrary when the persistence of inflation is long lived, the central bank is only able to achieve its objectives after a long period of time and thus considered as ineffective (Gerlach and Tillmann, 2010). While there have been a number of studies on interest rate smoothing; we are not aware of any study that has examined the implications of interest rate smoothing on the persistence and transmission of a monetary and a technology shock. Thus, this chapter examines the impact of interest rate smoothing on the persistence and transmission of a monetary and a technology shock. Before doing this, I need to develop a macroeconomic model which will be used in this exercise. The model is presented below.

## **2.1 The Model**

This section present a dynamic stochastic general equilibrium closed economy model, characterized by monopolistic competition in the goods market. I follow Galí (2008), however a through elaboration is contained in Galí (2008, Chapter 3), Woodford (2003, Chapter 3) and Walsh (2010, Chapter 8). I extend Galí (2008) by modifying the Taylor rule to include lagged interest rate similar to Rotemberg and Woodford (1991). Moreover, the model is extended further to include a Taylor rule comprising of past values of inflation, output and interest rate.

The model is comprised of households, corporate sector and the central bank. Households supply labour to firms, purchase goods for consumption and hold bonds. Firms hire labour and specialize in the production of a single good which is an imperfect

substitute for other goods. Thus, firms have monopoly power in setting prices in the spirit of Calvo (1983). Households and firms optimize in order to maximize their respective utilities and profits. The central bank decides the monetary policy stance. It is assumed further that the financial market is complete and hence households can insure themselves from idiosyncratic risks.

## 2.2 Household Preferences

In this section I present the demand side of the model, the optimality conditions and log-linearization thereof. The preferences of the household over consumption and leisure are assumed to be identical. The utility of the household in period  $t$  is given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\eta}}{1+\eta} \right], \quad (2.2.1)$$

where  $\sigma$  is the elasticity of intertemporal substitution.  $\eta$  denotes the elasticity of labor supply, it captures the sensitivity of employment/labor supply to changes in the wage. A big  $\eta$  implies a small elasticity that is a big wage change is required to induce an increase in labor supply.  $N_t$  stand for the household's labor supply at time  $t$ .  $E_t$  denotes the expectation at time  $t$ , while  $\beta$  is the intertemporal discount factor  $0 < \beta < 1$ .  $C_t$  is a Dixit-Stiglitz type aggregator of a composite consumption of goods:

$$C_t = \left( \int_0^1 C_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}, \quad (2.2.2)$$

where  $C_t(i)$  denotes the amount of good  $i$  consumed by the household in period  $t$ . Furthermore, it is assumed that there exist a continuum of goods indexed on the interval  $[0,1]$ .  $\varepsilon > 1$  is a measure of the elasticity of substitution between goods produced within the continuum. A bigger  $\varepsilon$  means more competitiveness, while a small  $\varepsilon$  denotes a



higher degree of imperfect competition. The household budget constraint in nominal terms is given by:

$$\int_0^1 P_t(i)C_t(i)di + Q_tB_t \leq B_{t-1} + W_tN_t + T_t, \quad (2.2.3)$$

where  $P_t(i)$  represents the price of the good  $i$ ,  $B_t$  is the quantity of one period, nominally riskless discount bond bought in period  $t$  and matures in period  $t+1$ ,  $Q_t$  is its price.  $W_t$  represents the wages paid for labor,  $T_t$  stands for other incomes including shares in the firm at time  $t$ . The household optimization problem can be split into two stages: In the first step the household allocates its consumption bundle in order to minimize the total expenditure which is required to achieve the desired level of the consumption index  $C_t$ . The second step consists of the household choosing its optimum consumption and labor supply. Solving the first step yields the demand function<sup>3</sup>:

$$C_t(i) = \left( \frac{P_t(i)}{P_t} \right)^{-\varepsilon} C_t, \quad (2.2.4)$$

where  $P_t \equiv \left( \int_0^1 P_t(i)^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}}$  stand for the aggregate price index<sup>4</sup>. The total consumption

expenditure can be expressed as:  $\int_0^1 P_t(i)C_t(i)di = P_tC_t$ . Given that, the household budget constraint can be re-written as:

$$P_tC_t + Q_tB_t \leq B_{t-1} + W_tN_t + T_t \quad (2.2.5)$$

The household maximizes the utility function (2.2.1) with respect to the budget constraint (2.2.5). The optimality conditions can be written as<sup>5</sup>:

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<sup>3</sup> Appendix (A).

<sup>4</sup> Appendix (A).

<sup>5</sup> Appendix (B).

$$C_t^\sigma N_t^\eta = \frac{W_t}{P_t} \quad (2.2.6)$$

The marginal rate of substitution between labor and consumption is equal to the real wage.

$$Q_t = \beta E_t \left\{ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \left( \frac{P_t}{P_{t+1}} \right) \right\} \quad (2.2.7)$$

Linearization of optimality conditions<sup>6</sup> is presented below, where from (2.2.6) we get:

$$w_t - p_t = \sigma c_t + \eta n_t \quad (2.2.8)$$

From (2.2.7) we get:

$$c_t = E_t \{c_{t+1}\} - \frac{1}{\sigma} (i_t - E_t \{\pi_{t+1}\} - \rho), \quad (2.2.9)$$

where the  $i_t \equiv -\log Q_t$  is the nominal interest rate at time  $t$ ,  $\rho \equiv -\log \beta$  is the discount rate, while  $\pi_{t+1} = p_t - p_{t+1}$  is the inflation rate between period  $t$  and  $t+1$ . (2.2.9) states that the marginal utility of consumption today is equal to the discounted future marginal utility of consumption and the real interest rate. I also add an ad-hoc log-linearized money demand function.

$$m_t - p_t = y_t - \theta i_t, \quad (2.2.10)$$

where  $\theta > 0$  is the interest semi elasticity of demand for money,  $m_t - p_t = \ln \left( \frac{M_t}{P_t} \right)$  is the demand for real balances,  $y_t$  stands for log of output, and  $i_t$  represent the nominal interest rate.

## 2.3 The Corporate Sector

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<sup>6</sup> Appendix (C).

In this section I present the production side of the model, which is comprised of the production technology, the link between the marginal cost, nominal wage and inflation, the aggregate price dynamics, optimal price setting, the relationship between the marginal cost and output gap and the New Keynesian Phillips curve.

### 2.3.1 Production Technology

It is assumed that there is a continuum of monopolistic firms and each firm produces a differentiated good  $i$ . The production function uses one input which is labor. A specific firm production function is assumed to be:

$$Y_t(i) = A_t N_t(i), \quad (2.2.11)$$

where  $i \in [0,1]$  represent an index specific to the firm.  $Y_t(i)$  and  $N_t(i)$  denotes the output and the labor input specific to firm  $i$  at time  $t$ .  $A_t$  is a technology/ labor productivity which is assumed to be common to all firms. It is assumed that there is a productivity shock  $a_t = \log(A_t)$  which follows an AR (1)<sup>7</sup> process.

$$a_t = \rho_a a_{t-1} + \varepsilon_t^a, \quad (2.2.12)$$

where  $\rho_a \in [0,1]$ . From (2.2.11) the aggregate production function can be written as:

$$Y_t = A_t N_t. \quad (2.2.13)$$

In log terms, the above can be expressed as:

$$y_t = a_t + n_t \quad (2.2.14)$$

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<sup>7</sup> Autoregressive of order 1.

### 2.3.2 Link between the Marginal Cost, Nominal Wage and Inflation.

To derive the marginal cost, we begin with the derivation of the total cost. The latter is derived by multiplying the total labor hours with the real wage. From (2.2.13) the total

labor hours can be expressed as:  $N_t = \left( \frac{Y_t}{A_t} \right)$ . Therefore, total cost can be defined as:

$$TC_t = \left( \frac{W_t}{P_t} \right) \left( \frac{Y_t}{A_t} \right).$$

The marginal cost is therefore given by:  $\frac{\partial TC_t}{\partial Y_t} = \partial \frac{\frac{W_t}{P_t} * \frac{Y_t}{A_t}}{\partial Y_t} = \left( \frac{W_t}{P_t} \right) \left( \frac{1}{A_t} \right)$ .

The above can be written more compactly as:  $MC_t = \left( \frac{W_t}{P_t} \right) \left( \frac{1}{A_t} \right)$ . In logs the expression

above can be written as:

$$mc_t = w_t - p_t - a_t \quad (2.2.15)$$

The marginal cost is an increasing function of the nominal wages, and a decreasing function of technology improvement and prices.

### 2.3.3 Aggregate Price Dynamics

The price-setting is staggered following Calvo (1983). In each period a firm faces a fixed probability  $1 - \omega$  of adjusting its price, irrespective of how long it has been since the last time it changed its price. However, a fraction  $\omega$  of firms keep their prices unchanged. Therefore,  $\omega$  is an index of price stickiness. The dynamics of the aggregate price is an average price of firms changing their prices as well as those that leave their prices unchanged which can be presented as follows:

$$P_t = \left[ \int_{B_t} P_{t-1}(i)^{1-\varepsilon} di + (1-\omega)(P_t^*)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}, \quad (2.2.16)$$

where  $P_t$  stands for the aggregate price level,  $B_t \subset [0, \omega]$  denotes the set of non-optimizing firms in period  $t$ , while  $P_t^*$  denotes the optimal price chosen by firms which has the chance to set new prices.

$$P_t = \left[ \omega (P_{t-1})^{1-\varepsilon} + (1-\omega) (P_t^*)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}$$

Dividing by  $P_{t-1}$  both sides we get:

$$\frac{P_t}{P_{t-1}} = \frac{1}{P_{t-1}} \left[ \omega P_{t-1}^{1-\varepsilon} + (1-\omega) P_t^{*1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}$$

$$\frac{P_t}{P_{t-1}} = \left[ \omega \frac{P_{t-1}^{1-\varepsilon}}{P_{t-1}} + (1-\omega) \frac{P_t^{*1-\varepsilon}}{P_{t-1}} \right]^{\frac{1}{1-\varepsilon}}$$

$$\frac{P_t}{P_{t-1}} = \left[ \omega + (1-\omega) \left( \frac{P_t^*}{P_{t-1}} \right)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}$$

$$\pi_t^{1-\varepsilon} = \left[ \omega + (1-\omega) \left( \frac{P_t^*}{P_{t-1}} \right)^{1-\varepsilon} \right], \quad (2.2.17)$$

where,  $\pi_t \equiv P_t - P_{t-1}$  is the inflation between time  $t-1$  and  $t$ . A log linearization of (2.2.17) around the zero inflation steady state yields.

$$(1-\varepsilon) \exp(\log(\pi_t)) = \exp(\log(\omega) + \exp(\log(1-\omega) + (1-\varepsilon)(P_t^* - P_{t-1}))$$

$$(1-\varepsilon) \exp(\log(\pi_t)) = \exp(\log(\omega) + \exp(\log(1-\omega) + (1-\varepsilon)(\pi_t^*))$$

where  $\pi_t^* = P_t^* - P_{t-1}$ . Thus,

$$(1-\varepsilon) \frac{\pi_t - \pi}{\pi} = (1-\omega) + (1-\varepsilon) \left( \frac{\pi_t^* - \pi}{\pi} \right) \text{ which is:}$$

$$\pi_t = (1-\omega) (p_t^* - p_{t-1}) \quad (2.2.)$$

2.2.18 states that inflation will rise if and only if firms having a chance of adjusting their prices decide to charge prices which are on average above the average prevailing prices.

### 2.3.4 Optimal Price Setting<sup>8</sup>

A firm faced with the decision to set the price today must do so taking into account that the newly reset price might affect future profits given the fact that there is a probability  $\omega^k$  that such a price may hold in period  $k$  ahead. Thus, a firm given a chance to re-optimize in period  $t$  will select  $P_t^*$  which maximise the current market value of its profits, while the set price remains effective. Thus it maximizes the following function.

$$\max_{P_t^*} \sum_{k=0}^{\infty} E_t \omega^k (Q_{t,t+k}) \left[ (P_t^* Y_{t+k/t} - \Psi_{t+k}(Y_{t+k/t})) \right], \quad (2.2.19)$$

subject to a sequence of demand constraints

$$Y_{t+k/t} = \left( \frac{P_t^*}{P_{t+k}} \right)^{-\varepsilon} C_{t+k}, \quad (2.2.20)$$

for  $k = 0, 1, 2, \dots$  where  $(P_t^*)$  is the price selected by the optimizing firm.  $\Psi_{t+k}(\cdot)$  is the cost function, while  $Y_{t+k/t}$  is the output in period  $t+k$ .  $Q_{t,t+k}$  denotes the stochastic discount factor or present value operator which is equal to the one which is faced by consumers  $\beta^k \left( \frac{C_{t+k}}{C_t} \right) \frac{P_t}{P_{t+k}}$ .

The first order condition for the optimal price can be written as:

$$\sum_{k=0}^{\infty} \omega^k E_t \left\{ Q_{t,t+k} Y_{t+k/t} \left[ P_t^* - M \psi_{t+k/t} \right] \right\} = 0, \quad (2.2.2)$$

where,  $M \equiv \frac{\varepsilon}{\varepsilon - 1}$  is the markup measuring the distortion caused by monopolistic competition.  $\psi_{t+k/t} \equiv \Psi'_{t+k}(Y_{t+k/t})$  is the marginal cost in period  $t+k$  for a firm which reset its price. In a world of perfect competition, firms would be able to set their prices equal to the marginal cost and the desired markup  $(P_t^* = M \cdot \psi_{t/t})$ . Thus the essence of price stickiness

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<sup>8</sup> Appendix (D).

is to preclude firms from selling their goods at the desired markup. Dividing (2.2.21) by  $P_{t-1}$ ,

$$\sum_{k=0}^{\infty} \omega^k E_t \left\{ Q_{t,t+k} Y_{t+k|t} \left( \frac{P_t^*}{P_{t-1}} - MC_{t+k|t} \Pi_{t-1,t+k} \right) \right\} = 0, \quad (2.2.22)$$

where  $MC_{t+k|t} \equiv \psi_{t+k|t} / P_{t+k}$  is the real marginal cost in period  $t+k$  for a firm which last reset its price in period  $t$ .  $\Pi_{t-1,t+k} \equiv P_{t+k} / P_{t-1}$  is the gross inflation between period  $t-1$  and  $t+k$ . It is assumed that in the zero inflation steady state  $P_t^* / P_{t-1} = 1$ ,  $\Pi_{t-1,t+k} = 1$ . This implies further that  $P_t^* = P_{t+k}$ . Moreover,  $Y_{t+k|t} = Y$  is constant and  $MC_{t+k|t} = MC$  given that the firm will produce the same quantity of output. A first order Taylor expansion of (2.2.22) around the zero inflation steady state yields:

$$p_t^* - p_{t-1} = (1 - \beta\omega) \sum_{k=0}^{\infty} (\beta\omega)^k E_t \left\{ mc_{t+k|t} + p_{t+k} - p_{t-1} \right\} \quad (2.2.23)$$

where  $mc_{t+k|t} \equiv mc_{t+k|t} - mc = mc_{t+k|t} + \log M = mc_{t+k|t} + \mu$ . Assuming a constant return to scale  $mc_{t+k|t} = mc_{t+k}$ , (2.2.23) can be presented as:

$$p_t^* = (1 - \beta\omega) \sum_{k=0}^{\infty} (\beta\omega)^k E_t \left\{ mc_{t+k} + p_{t+k} \right\}; \quad (2.2.24)$$

A firm given an opportunity to adjust its price will set the price as a markup over a weighted average of its current and expected marginal costs. Combining (2.2.24) with the optimal price (2.2.18) we derive the inflation equation.

$$\pi_t = \beta E_t (\pi_{t+1}) + \lambda mc_t, \quad (2.2.25)$$

where  $\lambda = \frac{(1-\omega)(1-\omega\beta)}{\omega}$  measures the elasticity of inflation to the real marginal cost.

(2.2.25) states that changes in the current inflation will be driven by contemporaneous movements in the real marginal cost and the expected future inflation.

### 2.3.5 Relationship between the Marginal Cost and the Output gap.

The output gap is defined as the difference between output realized under nominal rigidities  $y_t$  and the natural output  $y_t^n$ . The latter refers to output that would have been realized if prices were fully flexible. The marginal cost is related to output as follows: From (2.2.15) the economy's marginal cost is defined as:

$$mc_t = w_t - p_t - a_t$$

From  $w_t - p_t = \sigma c_t + \eta n_t$  the household utility optimization:

$$w_t - p_t = \eta n_t + \sigma c_t.$$

Using the goods market equilibrium condition  $y_t = c_t$ .

$$mc_t = \eta(y_t - a_t) + \sigma y_t - a_t, \quad (2.2.26)$$

$$mc_t = (\eta + \sigma)y_t - (1 + \eta)a_t. \quad (2.2.27)$$

In equilibrium output is at its natural level. In this case, the marginal cost is constant at its steady state value:  $mc = -\mu$ : Substituting this and the natural output into (2.2.27), we get:

$$mc = -\mu = (\eta + \sigma)y_t^n - (1 + \eta)a_t. \quad (2.2.28)$$

It is assumed that the policy preference of the firm is to keep the marginal cost constant in the case of flexible prices. Thus, setting  $(mc = 0)$  implies that  $y_t^n$  becomes:

$$y_t^n = \left( \frac{1 + \eta}{\sigma + \eta} \right) a_t. \quad (2.2.29)$$



(2.2.29) states that when prices are flexible, equilibrium output will be proportional to the productivity shock  $a_t$ . To derive the marginal cost gap we deduct (2.2.27) from (2.2.28):

$$mc_t = (\eta + \sigma) y_t - (1 + \eta) a_t - (\eta + \sigma) y_t^n - (1 + \eta) a_t, \quad (2.2.30)$$

$$mc_t = (\eta + \sigma) y_t - y_t^n,$$

$$mc_t = (\eta + \sigma) \tilde{y}_t, \quad (2.2.31)$$

where  $\tilde{y}_t$  denotes the output gap.

Combining  $\pi_t = \beta E_t(\pi_{t+1}) + \lambda mc_t$ , and (2.2.31) we derive the New Keynesian Phillips Curve<sup>9</sup>

$$\pi_t = \beta E_t(\pi_{t+1}) + \kappa \tilde{y}_t, \quad (2.2.32)$$

where  $\kappa = \lambda(\sigma + \eta)$ .

(2.2.32) states that inflation will be determined by excess demand represented by the output gap as well as the expected inflation.

## 2.4 Equilibrium

In the preceding section I present the goods market equilibrium of the model. The goods market clearing requires that

$$Y_t(i) = C_t(i), \quad i \in [0, 1] \text{ for all } i, t.$$

Defining the aggregate output as

$$Y_t \equiv \left( \int_0^1 Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}},$$

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<sup>9</sup> Appendix (D).

It follows that goods market clearing condition in the economy is:

$$Y_t = C_t.$$

Taking logs on both sides we get:

$$y_t = c_t. \quad (2.2.33)$$

Substituting (2.2.9) into (2.2.33) we derive:

$$y_t = E_t(y_{t+1}) - \frac{1}{\sigma}(i_t - (\pi_{t+1}) - \rho). \quad (2.2.34)$$

Subtracting the natural output from (2.2.34):

$$\begin{aligned} \tilde{y}_t \equiv y_t - y_t^n &= \left\{ \left[ E_t(y_{t+1} - y_{t+1}^n) - \frac{1}{\sigma}(i_t - E_t(\pi_{t+1}) - \rho - y_t^n + y_{t+1}^n) \right] \right\}, \\ \tilde{y}_t &= E_t(\tilde{y}_{t+1}) - \frac{1}{\sigma}(i_t - E_t(\pi_{t+1}) - r_t^n), \end{aligned} \quad (2.2.35)$$

where  $r_t^n = \rho + \sigma E_t(y_{t+1}^n - y_t^n)$  is the natural interest rate (Wicksellian interest rate) refers to the interest rate determined by real factors in the economy. This tells us that the output-gap is proportional to the deviations between the real and the natural interest rates. Using (2.2.29) the natural interest rate can be expressed as:

$$r_t^n = \rho + \sigma E_t \left( \frac{1+\eta}{\eta+\sigma} \right) a_{t-1} - a_t. \quad (2.2.36)$$

It follows that the natural interest rate is determined by changes in technology. After presenting the goods market equilibrium, output gap and the natural interest rate, I now introduce central bank, which is represented by the monetary policy rule.

## 2.5 Monetary Policy Rule(s)

This section presents the monetary policy rate rule(s) of the central bank. In particular, I assume a Taylor rule (non smoothing policy rule), where the interest rate responds to: contemporaneous inflation and the output gap.

$$i_t = \rho + \phi_\pi \pi_t + \phi_y \tilde{y}_t + v_t \quad (2.2.37)$$

where  $i_t$  represent the policy rate,  $v_t$  is a shock to interest rate, which is assumed to follow an AR (1) process  $v_t = \rho_v v_{t-1} + \varepsilon_t^v$ .  $\phi_\pi$  and  $\phi_y$  are the coefficients on inflation and output respectively. This rule does not capture the tendency of central banks to smooth the interest rate. Thus, I model interest rate smoothing by allowing the contemporaneous interest rate to responds to the past value of the interest rate, contemporaneous inflation and the output gap. This gives us a Taylor rule with lagged interest rate (smoothing policy rule) which follows:

$$i_t = \phi_i i_{t-1} + (1 - \phi_i) [\phi_\pi \pi_t + \phi_y \tilde{y}_t] + v_t, \quad (2.2.38)$$

$\phi_i$  is an interest rate smoothing parameter. Moreover the policy rule can be described as leaning against the wind in the sense that both the coefficients of inflation and the output gap are positive, i.e. the central bank raises the policy rate when either inflation or the output gap is above its target.

McCallum (1997) however criticises the Taylor rule considered above based on the fact that it requires the central bank to use current output and inflation data when setting the policy interest rate, given that such data may not be available then. Woodford (1999) states that, current output and inflation data may be unobservable by the central bank for two reasons: Firstly, economic data are more often collected retrospectively. Besides, data collection requires processing before the inherent information about the economy can be distilled. Secondly, even if the data was observable immediately the political process of responding to them takes time. To take this constraint into account, we extend the model further by supposing that the central bank instead responds to the output gap and inflation variations with a lag of one quarter. Thus, we modify the rule in 2.2.38 to the Backward looking Taylor rule as:

$$i_t = \phi_i i_{t-1} + (1 - \phi_i) [\phi_\pi \pi_{t-1} + \phi_y \tilde{y}_{t-1}] + v_t, \quad (2.2.39)$$

Woodford (1999) argues that using a policy rule similar to (2.2.39) would make the operations of the central bank more transparent to the public if the latter had such lagged data. Likewise, it will be easier for the public to detect when the central bank has deviated from the rule.

## 2.6 Model Calibration and Solution

The complete model can be presented by six endogenous variables and two shocks:

$$\textbf{Output gap: } \tilde{y}_t = E_t \{ \tilde{y}_{t+1} \} - \frac{1}{\sigma} (i_t - E_t \{ \pi_{t+1} \} - r_t^n) \quad (2.2.3)$$

$$\textbf{Ad-hoc Money Demand: } m_t - p_t = y_t - \theta i_t \quad (2.2.1)$$

$$\textbf{Phillips Curve: } \pi_t = \beta E_t \{ \pi_{t+1} \} + \kappa \tilde{y}_t \quad (2.2.32)$$

**Monetary Policy Rules:**

$$\textbf{Taylor rule: } i_t = \rho + \phi_\pi \pi_t + \phi_y \tilde{y}_t + v_t \quad (2.2.3)$$

$$\textbf{Taylor rule with lagged interest rate: } i_t = \phi_i i_{t-1} + (1 - \phi_i) [\phi_\pi \pi_t + \phi_y \tilde{y}_t] + v_t \quad (2.2.3)$$

$$\textbf{Backward looking Taylor rule: } i_t = \phi_i i_{t-1} + (1 - \phi_i) [\phi_\pi \pi_{t-1} + \phi_y \tilde{y}_{t-1}] + v_t, \quad (2.2.39)$$

$$\textbf{Monetary Policy Shock: } v_t = \rho_v v_{t-1} + \varepsilon_t^v \quad (2.2.3)$$

$$\textbf{Technology Shock: } a_t = \rho_a a_{t-1} + \varepsilon_t^a \quad (2.2.1)$$

**Table 1 Parameter values used in calibrating a Closed Economy Model<sup>10</sup>.**

Parameter	Value	Description
$\beta$	0.99	The discount factor
$\sigma$	1	Coefficient of risk aversion
$\eta$	1	Elasticity of labour supply
$\theta$	4	Sensitivity of interest rate to money demand
$\omega$	0.75	Measure of price stickiness
$\varepsilon$	6	Elasticity of demand
$\phi_i$	0.9	Sensitivity of the central bank with respect to interest rate (value as in Galí & Gertler 2007)
$\phi_\pi$	1.2	Sensitivity of the central bank with respect to inflation(value as in Rotemberg & Woodford 1999)
$\phi_y$	0.06	Sensitivity of the central bank with respect to the output gap (value as in Rotemberg & Woodford 1999)
$\rho_v$	0.5	Persistence of the monetary policy shock
$\rho_a$	0.9	Persistence of the technology shock
Parameters for the Backward looking Taylor rule		
$\phi_i$	0.9	Sensitivity of the central bank with respect to interest rate (value as in Galí & Gertler, 2007)
$\phi_y$	0.08	Sensitivity of the central bank with respect to the output gap (value as in Rotemberg & Woodford, 1999)
$\phi_\pi$	1.27 <sup>11</sup>	Sensitivity of the central bank wrt the inflation rate ( as in Rotemberg & Woodford, 1999)

<sup>10</sup> The model was solved numerically using the Dynare algorithm in Matlab. Most model parameters are as in Galí (2008) unless stated otherwise.

<sup>11</sup> The inflation and output parameters are higher in Backward Looking Taylor rule compared to the Taylor rule. This can be explained by the fact the monetary authority has to aggressively respond to past inflation and output gap variables to ensure determinacy (Carlstrom and Fuerst, 2000).

## 2.7 Results

This section presents the results of the impact of interest rate smoothing on the persistence of a monetary and technology shock using the impulse response functions. More specifically, Sub section 2.7.1 presents the comparison of the impulse responses of a monetary policy shock between the Taylor policy rule(2.2.37) and Taylor with a lagged interest rate policy rule(2.2.38) and the backward looking Taylor rule(2.2.39). Sub section 2.7.2 compares the impulse responses to a technology shock under the three policy rules. Sub section 2.7.3 concludes.

### 2.7.1 Monetary Policy Shock

The impulse responses to a monetary policy shock of about 0.25 basis points are depicted in Figure 1. The dotted line denotes the impulses from a policy rule of a Taylor rule with lagged interest rate, the marked line symbolise the Taylor rule. The backward looking Taylor policy rule is represented by the bold line. The model predicts that a positive monetary shock induces an increase in the nominal and the real interest rate. The resultant increase in the real interest rate causes a decline in the current output relative to the future expected output, because economic agents consider current consumption to be cheaper than the future consumption. This subsequently leads to a decrease in the output gap and inflation in the next period. Money supply decline, and thus the model predicts a liquidity effect similar to Galí (2008).

However, the impulses from the Taylor with lagged interest rate and backward looking Taylor rule (interest rate smoothing) are more persistent than those of Galí (2008) or the Taylor rule. When the central bank follows a Taylor rule (contemporaneous policy rule), this model predicts that the impulses to a monetary policy shock persist for eight periods and a half. The impulses persist further (ten periods and a half) when the central bank follows the Taylor rule with lagged interest rate or the backward looking Taylor rule. The

innovations return gradually to the steady state in the Taylor rule with lagged interest rate or backward looking Taylor rule.

Thus, in this model an interest rate smoothing policy rule (Taylor rule with lagged interest rate or backward looking Taylor rule) induces long lived persistence compared to a contemporaneous policy rule (Taylor rule). The Taylor rule with lagged interest rate compounds the impact of the shock on most of the variables in the period which follows the shock. The backward looking Taylor rule induces a more severe impact on the money supply, real interest rate and nominal interest than the Taylor rule with lagged interest rate and the Taylor rule respectively. A detailed analysis of the response of each variable is presented in the rest of this section.

As explained earlier, the nominal interest rate increases following the monetary shock. The immediate effect (first period after the shock) of the Taylor with lagged interest rate is to moderate the impact of the shock on the nominal interest rate to 3 basis points (annualised) from 4 basis points (annualised) in the Taylor rule. The backward looking Taylor policy rule tends to compound the impact of the shock on the nominal interest rate to 1 per cent annualised. The persistence increase from eight and half in the Taylor rule (non interest rate smoothing policy rule) to approximately ten periods and half in the Taylor rule with lagged interest rate and backward looking Taylor policy rule (interest rate smoothing rules).

Similarly, the Taylor rule with lagged interest rate intensifies the increase in the real interest rate to 4 percent annualised from 6 basis points annualised in the Taylor rule. The backward looking Taylor policy rule intensifies the increase in the real rate to 4 per cent annualised. The Taylor rule with lagged interest rate and the backward looking Taylor policy rule compound the impact of the monetary shock on inflation. In the period which follows the shock, the decline in inflation increases to minus 5 per cent annualised in both policies from a relatively lower decline of minus 4 basis points annualised in the Taylor rule.

A one per cent increase in the policy rate reduces the output gap by minus 1.3 per cent when the central bank follows a Taylor rule. The impact is increased further to minus 10.5 per cent and 10 per cent in the Taylor rule with lagged interest rate and the backward looking Taylor rule respectively. The contraction in the money supply increase to minus 16 and 18 per cent annualised in the Taylor rule with lagged interest rate and the backward looking Taylor policy rule respectively from minus 3 per cent annualised in the Taylor rule. The persistence increases from seven periods (Taylor rule) to ten periods and half in the Taylor with lagged interest rate and the backward looking Taylor rule respectively.

The persistence of the policy rate is the same in all the policy rules. Thus, the high persistence observed on variables in the Taylor with lagged interest rate and the backward looking Taylor rule can be ascribed to the lagged interest rate which enters the policy function of the central bank. To summarise, the persistence of the monetary policy shock is truncated in a Taylor rule compared to the Taylor with lagged interest rate and the backward looking Taylor rule. Moreover, it eases the impact of the shock on variables. Interest rate smoothing policies (Taylor with lagged interest rate or backward looking Taylor rule), increases the persistence of the monetary policy shock, and increases the impact of the shock on variables. Based on the persistence and volatility of inflation therefore, the Taylor rule is considered superior to the Taylor with lagged interest rate or backward looking Taylor rule.

### **2.7.2 Technology Shock**

Figure 2 show the impulse responses to a 10 per cent technology shock. The shock reduces the nominal interest rate, inflation, the output gap while it increases the money supply. Similar to the monetary shock, the model predicts a liquidity effect. Except on the real interest rate, the persistence of a technology shock tends to be truncated in the Taylor rule with lagged interest rate and the backward looking Taylor policy rule. This is contrary to a monetary policy shock in which the Taylor rule with lagged interest rate and the backward looking Taylor policy rule protract the persistence.



Likewise, the effects of the shock on these variables tend to be mixed. For instance, the Taylor rule with lagged interest rate and the backward looking Taylor rule tend to increase the impact of the technology shock on the output gap, while it eases the impact on the nominal interest rate. However, the effects of the shock on the real interest rates and money supply tend to be divergent in the Taylor rules compared to the two interest rate smoothing policy rules (Taylor rule with lagged interest rate and backward looking Taylor rule). A detailed analysis of the impact and persistence of the shock on each variable is presented below.

After the shock, the decline in the nominal interest rate eases from minus 3 per cent in the Taylor rule to minus 3 basis points in the Taylor with lagged interest rate policy rule. The impulse persistence extends beyond 20 periods in both the Taylor rule and the backward looking Taylor rule. In the Taylor rule with lagged interest rate however, the impulse persist for six periods only. The decline in inflation decrease to minus 2.4 per cent and 2.2 per cent in the Taylor with lagged interest rate and the backward looking Taylor rule from minus 2.5 per cent in the Taylor rule. The persistence is also reduced considerably to 10 periods in the Taylor rule with lagged interest rate and backward looking Taylor policy rule. On the other hand, the persistence extends beyond 20 periods in the Taylor rule.

The output gap decline further by 6 per cent and 5 per cent in the Taylor with lagged interest rate and the backward looking Taylor rule respectively, from minus 2 per cent in the Taylor policy rule. Similarly, the persistence of the output gap declines to 10 periods in the Taylor with lagged interest rate and the backward looking Taylor rule. In the Taylor rule however the output gap persists beyond 20 periods. The money supply growth declines significantly by minus 6 per cent in the backward looking Taylor policy rule as well as the Taylor with lagged interest rate policy rule from an expansion of 8 per cent in the Taylor rule. The persistence is however long lived and persists beyond 20 periods in both policy regimes. Unlike the case of a monetary policy shock, the persistence of the shock is long lived in the in the Taylor with lagged interest rate and the backward looking Taylor rule compared to the Taylor rule. Accordingly, based on the persistence and

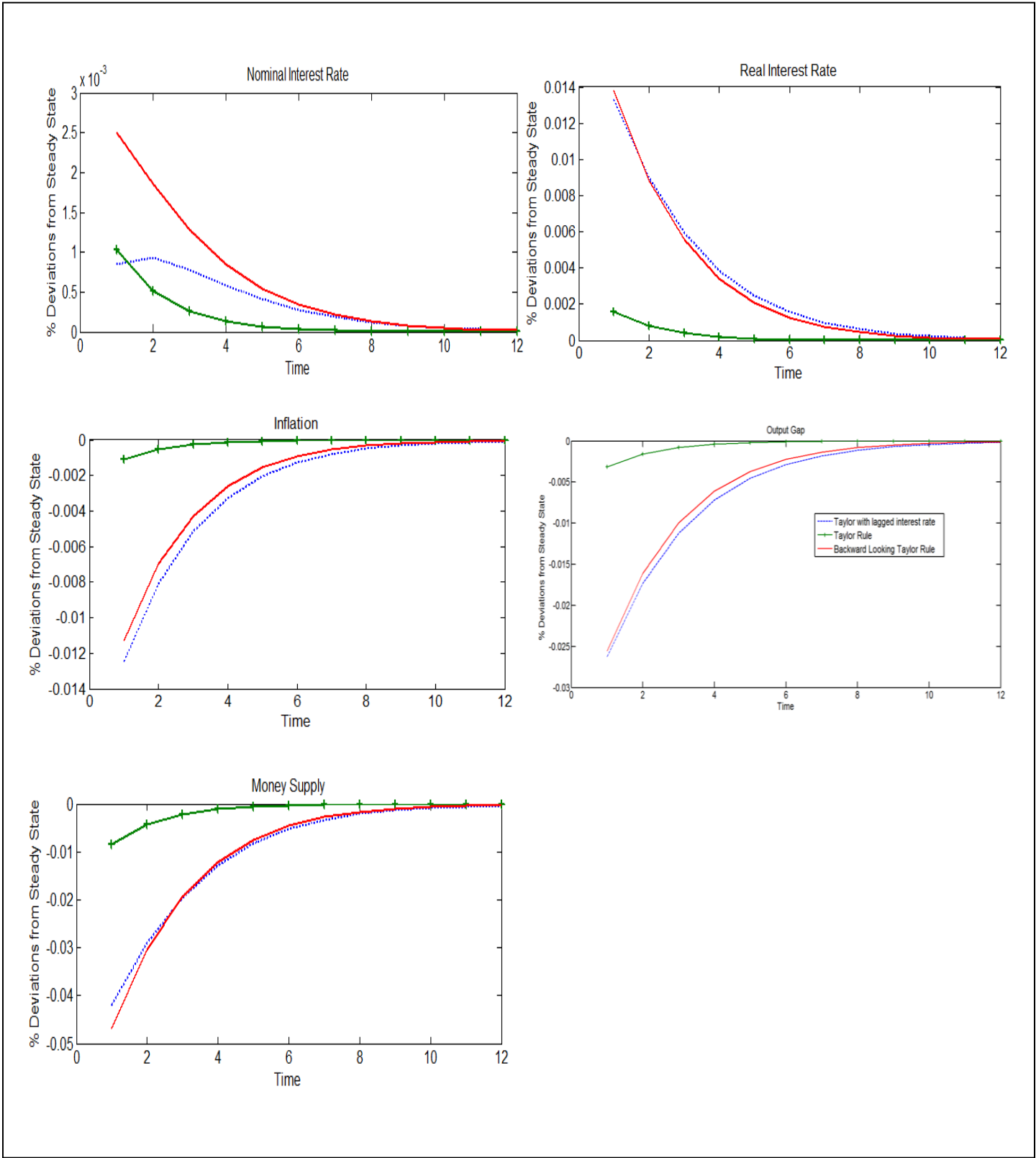
volatility of inflation, the Taylor with lagged interest rate and backward looking Taylor rule are considered as superior to the Taylor rule given that they reduce the persistence and volatility of the shock. This tends to suggest that a policy maker faces a trade off as to which policy rule to select. In case of a monetary policy shock, the Taylor rule is superior in terms of reducing the persistence and volatility of the shock on inflation, while in case of a Technology shock, the interest smoothing policy rules (Taylor rule with lagged interest rate and the backward looking Taylor rule) are superior to the Taylor rule.

### **2.7.3 Conclusion**

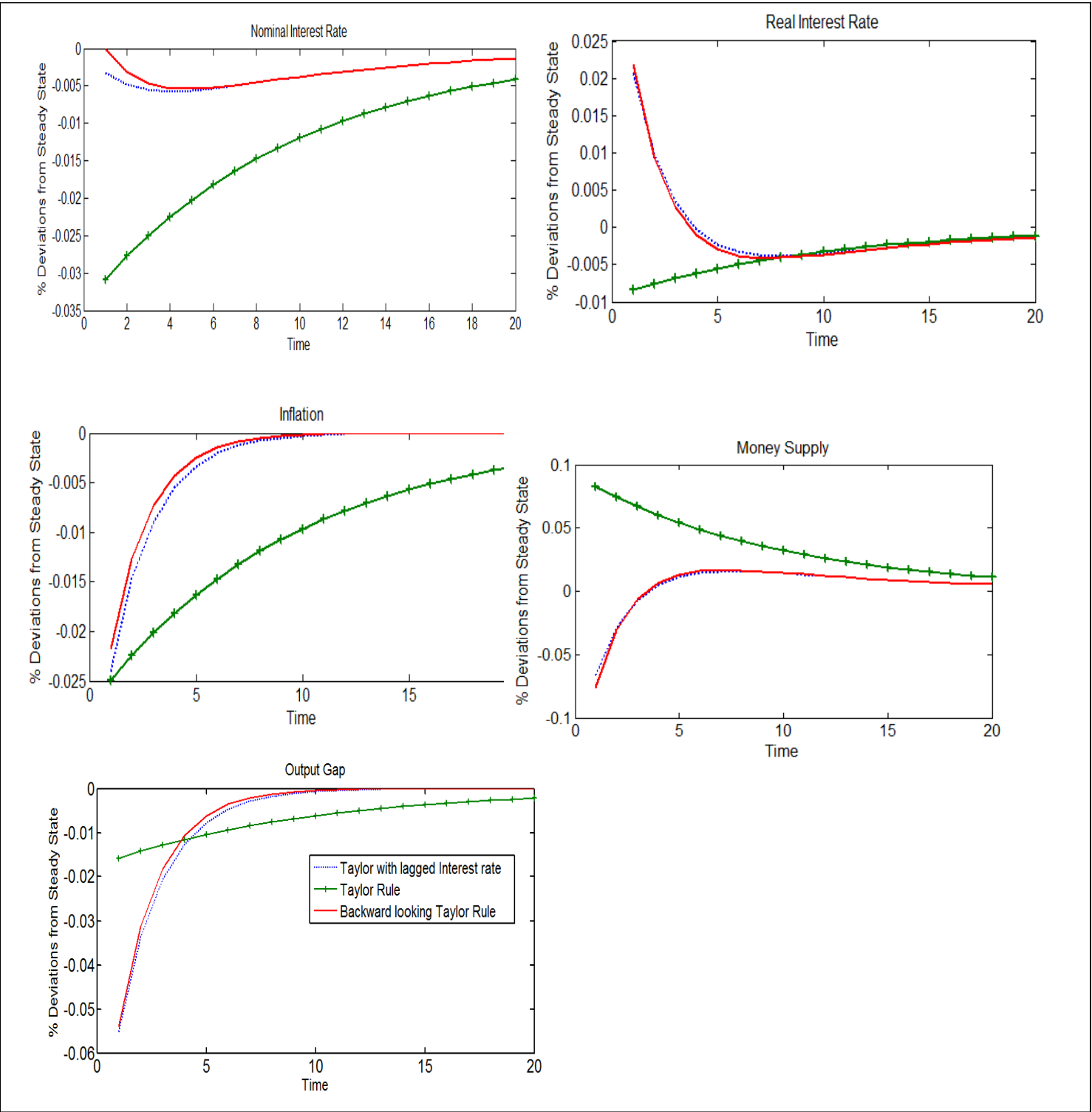
The aim of this chapter was to evaluate the impact of interest rate smoothing on the persistence of both a monetary and technology shock in a DSGE model. It can be concluded that, in this model, interest rate smoothing rules (Taylor with lagged interest rate or the backward looking Taylor rule) elongates the persistence of a monetary shock, while it truncates the persistence of a technology shock. Moreover, the Taylor rule with lagged interest rate compounds the impact of a monetary shock on the nominal interest rate, inflation, the output gap and money supply. The impact of the backward looking Taylor policy rule on the same variables is similar except on the nominal interest rate. The Taylor rule on the otherhand shortens the persistence of a monetary policy shock.

Assuming that the objective of the central bank is to reduce the persistence and volatility of the shock on inflation, the Taylor rule is considered superior to the Taylor rule with lagged interest rule or the backward looking Taylor rule when the economy is hit by a monetary policy shock. On the contrary, a positive technology shock reduces the nominal interest rate, inflation, the output gap while it increases the money supply. Moreover, interest smoothing rules tend to truncate the persistence of the technology shock. Thus, the Taylor rule with lagged interest rate and the backward looking Taylor rule is considered superior to the Taylor rule when the economy is faced with a technology shock. Galí (2008) obtained short lived persistence due to a monetary policy shock and long lived persistence due to technology shock, similar to those displayed in the Taylor rule.

**Figure 1    Impulse Responses to a Monetary Shock**



**Figure 2   Impulse Responses to a Technology Shock**



## Appendix (A) Derivation of (2.2.4).

The household maximizes total expenditure on good:  $C_t \equiv \left( \int_0^1 C_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}$  subject to

the constraint:  $\int_0^1 P_t(i) C_t(i) di = Z_t$

In order to solve the maximization problem, we first set out the Lagrangian Function:

$$L(C_t(i)) = \left( \int_0^1 C_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}} - \lambda_t \left( \int_0^1 P_t(i) C_t(i) di - Z_t(i) \right)$$

The first order condition is:  $\frac{\partial L}{\partial C_t(i)} = 0$

$$\frac{\partial L}{\partial C_t(i)} = \left[ \left( \frac{\varepsilon}{\varepsilon-1} \right) \left( \int_0^1 C_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}-1} \right] \left( \frac{\varepsilon-1}{\varepsilon} \right) C_t(i)^{\frac{\varepsilon-1}{\varepsilon}-1} - \lambda_t P_t(i) = 0$$

$$\left( \int_0^1 C_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{1}{\varepsilon-1}} C_t(i)^{-\frac{1}{\varepsilon}} - \lambda_t P_t(i) = 0$$

$$\lambda_t \left( C_t(i)^{\frac{1}{\varepsilon}} \right) C_t(i)^{-\frac{1}{\varepsilon}} = P_t(i)$$

$$C_t(i) = \left[ \frac{P_t(i)}{\lambda_t} \right]^{-\varepsilon} C_t$$

$$C_t \equiv \left[ \left( \int_0^1 \left( \frac{P_t(i)}{\lambda_t} \right)^{-\varepsilon} C_t \right)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}}$$

$$C_t \equiv C_t \lambda_t^\varepsilon \left[ \left( \int_0^1 (P_t(i))^{1-\varepsilon} di \right)^{\frac{\varepsilon}{\varepsilon-1}} \right]^{\frac{\varepsilon}{\varepsilon-1}}$$

$$C_t(i) = \left[ \frac{P_t(i)}{P_t} \right]^{-\varepsilon} C_t \tag{2.2.4}$$

The End.

## Appendix (B) Derivation of (2.2.6–2.2.7).

The household maximizes utility:  $E_0 \sum_{t=1}^{\infty} \beta^t \left\{ \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\eta}}{1+\eta} \right\}$  subject to the constraint:

$$P_t C_t + Q_t B_t \leq B_{t-1} + W_t N_t + T_t$$

In order to solve the maximization problem, we first set out the Lagrangian Function:

$$L = E_0 \sum_{t=1}^{\infty} \beta^t \left\{ \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\eta}}{1+\eta} + \varphi_t \{ B_{t-1} + W_t N_t + T_t - P_t C_t - Q_t B_t \} \right\}$$

$$\frac{\partial L}{\partial C_t} = (1-\sigma) \frac{C_t^{1-\sigma-1}}{1-\sigma} - \varphi_t P_t = 0$$

$$C_t^{-\sigma} = \varphi_t P_t ; \quad \text{Also note, } \varphi_t = \frac{C_t^{-\sigma}}{P_t}$$

Therefore:  $C_{t+1}^{-\sigma} = \varphi_{t+1} P_{t+1}$

$$\frac{\varphi_{t+1}}{\varphi_t} = \left[ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right]$$

$$\frac{\partial L}{\partial N_t} = -(1+\eta) \frac{N_t^{1+\eta-1}}{1+\eta} + \varphi_t W_t = 0$$

$$N_t^\eta = \varphi_t W_t$$

$$N_t^\eta = \frac{C_t^{-\sigma}}{P_t} W_t$$

$$C_t^\sigma N^\eta = \frac{W_t}{P_t} \tag{2.2.6}$$

$$\frac{\partial L}{\partial B_t} = -\varphi_t Q_t + \beta(\varphi_{t+1}) = 0$$

$$Q_t = \beta \frac{\varphi_{t+1}}{\varphi_t}$$

$$Q_t = \beta \left\{ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right\}$$

The End.



## Appendix (C) Derivation of (2.2.8–2.2.9).

Linearizing the optimality conditions

Consumption/labor choice (2.2.6)

$$C_t^\sigma N_t^\eta = \frac{W_t}{P_t}$$

$$\sigma \ln C_t + \eta \ln N_t = \ln W_t - \ln P_t$$

$$\sigma c_t + \eta n_t = w_t - p_t \quad (2.2.8)$$

Present and future consumption choice (2.2.7)

$$\text{Given } Q_t = \beta \left\{ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right\}$$

Taking logs

$$\ln Q_t = \ln \beta - \sigma \ln C_{t+1} + \sigma \ln C_t + \ln P_t - \ln P_{t+1}$$

Solving for  $C_t$

$$-\sigma \ln C_t = -\sigma \ln C_{t+1} - \ln(Q_t) + \ln P_t - \ln P_{t+1} + \ln \beta$$

$$c_t = E_t \{c_{t+1}\} - \frac{1}{\sigma} (i_t - E_t \{\pi_{t+1}\} - \rho) \quad (2.2.9)$$

Where  $i_t \equiv -\ln Q_t$ ;  $\pi_{t+1} = p_t - p_{t+1}$  and  $\rho \equiv -\ln \beta$

The End.

## Appendix (D) Derivation of (2.2.21–2.2.25).

The firm wants to maximize the profit function

$$\frac{\max}{P_t^*} \sum_{k=0}^{\infty} \omega^k E_t(Q_{t,t+k}) \left[ \left( P_t^* Y_{t+k|t} - \Psi_{t+k}(Y_{t+k|t}) \right) \right]$$

Subject to a sequence of demand constraints

$$Y_{t+k|t} = \left( \frac{P_t^*}{P_{t+k}} \right)^{-\varepsilon} C_{t+k}$$

$$k = 0, 1, 2$$

Substituting for the sequence of demand constraints, we get.

$$\frac{\max}{P_t^*} \sum_{k=0}^{\infty} \omega^k E_t(Q_{t,t+k}) \left[ \left( P_t^* \left( \frac{P_t^*}{P_{t+k}} \right)^{-\varepsilon} C_{t+k} - \Psi_{t+k} \left( \frac{P_t^*}{P_{t+k}} \right)^{-\varepsilon} C_{t+k} \right) \right]$$

The first order condition with respect to the optimality price  $P_t^*$  is:

$$\sum_{k=0}^{\infty} \omega^k E_t \left\{ Q_{t,t+k} \left( \left( \frac{1}{P_{t+k}} \right)^{-\varepsilon} C_{t+k} (1-\varepsilon) (P_t^*)^{-\varepsilon} - \Psi'_{t+k} \left( \left( \frac{1}{P_{t+k}} \right)^{-\varepsilon} C_{t+k} (-\varepsilon) (P_t^*)^{-\varepsilon-1} \right) \right) \right\} = 0$$

$$\sum_{k=0}^{\infty} \omega^k E_t(Q_{t,t+k}) \left[ \left( (1-\varepsilon) \left( \frac{P_t^*}{P_{t+k}} \right)^{-\varepsilon} C_{t+k} + \Psi'_{t+k} \left( \frac{P_t^*}{P_{t+k}} \right)^{-\varepsilon} (\varepsilon) \frac{1}{P_t^*} C_{t+k} \right) \right] = 0$$

$$\sum_{k=0}^{\infty} \omega^k E_t(Q_{t,t+k} Y_{t+k|t}) \left[ \left( (1-\varepsilon) + \Psi'_{t+k} Y_{t+k|t} (\varepsilon) \frac{1}{P_t^*} \right) \right] = 0$$

$$\left( \frac{1-\varepsilon}{P_t^*} \right) \sum_{k=0}^{\infty} \omega^k E_t(Q_{t,t+k} Y_{t+k|t}) \left[ \left( P_t^* - \Psi'_{t+k} Y_{t+k|t} \left( \frac{\varepsilon}{\varepsilon-1} \right) \right) \right] = 0$$

$$\sum_{k=0}^{\infty} \omega^k E_t(Q_{t,t+k} Y_{t+k|t}) \left[ \left( P_t^* - \left( \frac{\varepsilon}{\varepsilon-1} \right) \Psi'_{t+k} Y_{t+k|t} \right) \right] = 0,$$

We can re-write the above equation as

$$\sum_{k=0}^{\infty} \omega^k E_t (Q_{t,t+k} Y_{t+k|t}) \left[ (P_t^* - M \psi_{t+k|t}) \right] = 0, \quad (2.2.21)$$

where,  $M = \frac{\varepsilon}{\varepsilon - 1}$  stands for the mark up due to monopolistic competition.

$\psi_{t+k|t} = \Psi'_{t+k} Y_{t+k|t}$  is the nominal marginal cost.

We log-linearize the optimal price setting equation about the zero inflation steady state.

To do so we, re-write the equation above in terms of variables which have well defined steady state and divide by  $P_{t-1}$ .

$$\sum_{k=0}^{\infty} \omega^k E_t \left\{ Q_{t,t+k} Y_{t+k|t} \left( \frac{P_t^*}{P_{t-1}} - M \frac{\psi_{t+k|t}}{P_{t+k}} \frac{P_{t+k}}{P_{t-1}} \right) \right\} = 0,$$

This becomes:

$$\sum_{k=0}^{\infty} \omega^k E_t \left\{ Q_{t,t+k} Y_{t+k|t} \left( \frac{P_t^*}{P_{t-1}} - M MC_{t+k|t} \Pi_{t-1,t+k} \right) \right\} = 0, \quad (2.2.22)$$

where  $MC_{t+k|t} \equiv \psi_{t+k|t} / P_{t+k}$  is the real marginal cost in period  $t+k$  for a firm which last reset its price in period  $t$ .  $\Pi_{t-1,t+k} \equiv P_{t+k} / P_{t-1}$  is the gross inflation between  $t-1$  and  $t+k$ .

It is assumed that in the zero inflation steady state  $P_t^* / P_{t-1} = 1$ ;  $\Pi_{t-1,t+k} = 1$ . This implies further that  $P_t^* = P_{t+k}$ . Moreover,  $Y_{t+k|t} = Y$  (constant) and  $MC_{t+k|t} = MC$ . Furthermore,

$$Q_{t,t+k} = \left( \frac{C_{t+k}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+k}} = \beta^k$$

Thus we re-write (2.2.23) as, ignoring  $Y_{t+k|t}$

$$\sum_{k=0}^{\infty} (\beta \omega)^k E_t \left\{ \frac{P_t^*}{P_{t-1}} - M MC_{t+k|t} \Pi_{t-1,t+k} \right\} = 0$$

Log-linearizing around the zero inflation steady state.

$$\sum_{k=0}^{\infty} (\beta \omega)^k E_t \left\{ \left( \exp(p_t^* - p_{t-1}) \right) - \exp(\mu + mc_{t+k|t} + p_{t+k} - p_{t-1}) \right\} = 0.$$

where  $\mu \equiv \log(M)$ .

$$\sum_{k=0}^{\infty} (\beta\omega)^k E_t \left\{ \left(1 + p_t^* - p_{t-1}\right) + \left(1 + mc_{t+k|t} + p_{t+k} - p_{t-1}\right) \right\} = 0$$

where  $mc_{t+k|t} \equiv mc_{t+k|t} - mc = mc_{t+k|t} + \log M = mc_{t+k|t} + \mu$ .

Re-arranging the terms

$$\begin{aligned} \sum_{k=0}^{\infty} (\beta\omega)^k E_t (p_t^* - p_{t-1}) &= \sum_{k=0}^{\infty} (\beta\omega)^k E_t \{ mc_{t+k|t} + p_{t+k} - p_{t-1} \} \\ p_t^* - p_{t-1} &= (1 - \beta\omega) \sum_{k=0}^{\infty} (\beta\omega)^k E_t \{ mc_{t+k|t} + p_{t+k} - p_{t-1} \} \end{aligned} \quad (2.2.23)$$

Assuming constant return to scale  $mc_{t+k|t} = mc_{t+k}$ , (2.2.23) can be presented as:

$$p_t^* = (1 - \beta\omega) \sum_{k=0}^{\infty} (\beta\omega)^k E_t \{ mc_{t+k} + p_{t+k} \} \quad (2.2.24)$$

$$p_t^* = \beta\omega E_t (p_{t+1}^*) + (1 - \beta\omega) (mc_t + p_t)$$

$$p_t^* - p_{t-1} = \beta\omega E_t (p_{t+1}^* - p_t) + (1 - \beta\omega) mc_t + \pi$$

Combine with the optimal price  $\pi_t = (1 - \omega) p_t^* - p_{t-1}$

$$\frac{1}{1 - \omega} \pi_t = \beta\omega E_t \frac{1}{1 - \omega} \pi_{t+1} + (1 - \beta\omega) mc_t + \pi_t$$

$$\left( \frac{1}{1 - \omega} - 1 \right) \pi_t = \frac{\omega}{1 - \omega} \beta E_t \pi_{t+1} + (1 - \beta\omega) mc_t$$

$$\pi_t = \beta E_t \pi_{t+1} + \lambda mc_t \quad (2.2.25)$$

$$\text{where } \lambda = \frac{(1 - \omega)(1 - \omega\beta)}{\omega}$$

The End

## 2.8 Model solution (Analytical)

Derivation of the output gap

$$\tilde{y}_t = E_t \tilde{y}_{t+1} - \frac{1}{\sigma} (\rho + \phi_\pi \pi_t + \phi_y \hat{y}_t + v_t - E_t(\pi_{t+1}) - r_t^n),$$

$$\tilde{y}_t = E_t \tilde{y}_{t+1} - \frac{1}{\sigma} [\phi_\pi (\beta E_t \pi_{t+1} + \kappa \tilde{y}_t) + \phi_y \hat{y}_t + v_t - E_t \pi_{t+1} - \tilde{r}_t^n],$$

$$\tilde{r}_t^n = r_t^n - \rho$$

$$\tilde{y}_t = E_t \tilde{y}_{t+1} - \frac{1 - \beta \phi_\pi}{\sigma} E_t \pi_{t+1} - \frac{\phi_\pi \kappa + \phi_y}{\sigma} \hat{y}_t + \frac{\tilde{r}_t^n - v_t}{\sigma}$$

$$\frac{\sigma \phi_\pi \kappa + \phi_y}{\sigma} \hat{y}_t = E_t \tilde{y}_{t+1} + \frac{1 - \beta \phi_\pi}{\sigma} E_t \pi_{t+1} + \frac{\tilde{r}_t^n - v_t}{\sigma}$$

$$\tilde{y}_t = \frac{1}{\sigma + \phi_\pi \kappa + \phi_y} [\sigma E_t \tilde{y}_{t+1} + (1 - \beta \phi_\pi) E_t \pi_{t+1} + (\tilde{r}_t^n - v_t)]$$

Current output- gap depends on the expected output gap expected inflation and shocks.

Derivation of inflation

$$\pi_t = \beta E_t \pi_{t+1} + \kappa \left\{ \frac{1}{\sigma \phi_\pi \kappa + \phi_y} [\sigma E_t \tilde{y}_{t+1} + (1 - \beta \phi_\pi) E_t \pi_{t+1} + (\tilde{r}_t^n - v_t)] \right\}$$

$$\pi_t = \frac{1}{\sigma + \phi_\pi \kappa + \phi_y} \left\{ \sigma \kappa \tilde{y}_{t+1} + [\kappa + \beta(\sigma + \phi_y)] E_t \pi_{t+1} + \kappa (\tilde{r}_t^n - v_t) \right\}$$

Expressing the two equations above as a system of forward looking difference equations:

$$\begin{aligned} \begin{bmatrix} \tilde{y}_t \\ \pi_t \end{bmatrix} &= \frac{1}{\sigma + \phi_\pi \kappa + \phi_y} \begin{bmatrix} \sigma & 1 - \beta \phi_\pi \\ \sigma \kappa & \kappa + \beta(\sigma + \phi_y) \end{bmatrix} \begin{bmatrix} E_t \tilde{y}_{t+1} \\ E_t \pi_{t+1} \end{bmatrix} + \begin{bmatrix} 1 \\ \kappa \end{bmatrix} (\tilde{r}_t^n - v_t) \\ &= \Omega \begin{bmatrix} \sigma & 1 - \beta \phi_\pi \\ \sigma \kappa & \kappa + \beta(\sigma + \phi_y) \end{bmatrix} \begin{bmatrix} E_t \tilde{y}_{t+1} \\ E_t \pi_{t+1} \end{bmatrix} + \Omega \begin{bmatrix} 1 \\ \kappa \end{bmatrix} (\tilde{r}_t^n - v_t) \end{aligned}$$

$$= A_T \begin{bmatrix} E_t \tilde{y}_{t+1} \\ E_t \pi_{t+1} \end{bmatrix} + B_T (\hat{r}_t^n - v_t)$$

where:

$$\Omega = \frac{1}{\sigma + \phi_\pi \kappa + \phi_y};$$

$$A_T = \Omega \begin{bmatrix} \sigma & 1 - \beta \phi \pi \\ \sigma \kappa & \kappa + \beta (\sigma + \phi y) \end{bmatrix} \text{ stands for the expectations on current output gap and inflation.}$$

$$B_T = \Omega \begin{bmatrix} 1 \\ \kappa \end{bmatrix} \text{ Effects of technology shock on } \hat{r}_t^n \text{ and monetary policy shocks on } v_t$$

The End.

## **Chapter 3 Cost Push Shock and Monetary Policy Rules.**

### **3.0 Introduction and Literature Review.**

This chapter aims to address the question of which monetary policy rule (targeting rule or instrument rules) performs better in the presence of a cost push shock. It is motivated by the great moderation (the period from 1993 to 2006) which was characterised by low and stable inflation in developed economies. Credit to this is attributed to the inflation targeting framework which was adopted by many countries, developed, developing and emerging markets. Scott (2010) for instance records that a total number of 26 countries had implemented Inflation Targeting by March 2010. This has prompted renewed interest on research in monetary policy rules and their effects on the economy. For instance Clarida et al. (1999) states that this area of research has been inspired by the empirical findings of the short-term non-neutrality of monetary policy and developments in the theoretical frameworks such as sticky price dynamic general equilibrium models which are used to evaluate policies.

A number of studies have examined the performance of different monetary policy regimes. For instance, King and Wolman (1999), Goodfriend and King (2001) and Woodford, (2003) suggest that a policy which targets inflation strictly will maximise welfare in a closed economy setting. Aoki (2001) addresses the question of an open economy facing sector specific supply shocks. He shows that a policy which fully stabilise the inflation in the sticky price sector is the optimal monetary policy because it also maximizes household welfare. He suggests that the central bank should target core inflation (inflation in the sticky-price sector) rather than a broad measure of inflation. Additionally, his model predicts that policies which stabilize the output gap or the core inflation are complementary.

Clarida et al. (2001) argue that when the exchange rate path through is perfect, monetary policy should allow the exchange rate to float and rather target domestic

inflation. Their work was an extension of Richard Clarida, Jordi Galí and Mark Gertler (1999) carried over to a small open economy. They present a normative analysis of monetary policy within a simple optimization-based closed economy framework and derive the optimal policy rule. They show that using their parameterization, the design of monetary policy for the small open economy is isomorphic to the problem of the closed economy.

Similarly, Galí and Monacelli (2002) and Galí 2005 contend that a policy which targets domestic inflation is optimal in the open economy. They develop and analyse a tractable optimizing model of a small open economy with staggered price setting as in Calvo (1980). They show that the equilibrium dynamics for that model economy is a canonical representation of a closed economy. The only difference between the small open economy model and its closed economy counterpart is due to two features: first, some coefficients, i.e. the degree of openness and substitutability of goods produced in different countries depend on parameters which are specific to small open economy, and second, the natural levels of output and interest rates in the small open economy are generally a function of both domestic and foreign disturbances.

In addition, they show how the welfare level of alternative monetary policy rules can be evaluated. The loss function of the model is similar to the corresponding closed economy and penalizes fluctuations in domestic inflation and the output gap. They use the model to analyse the properties of three alternative monetary regimes for the small open economy namely, a domestic inflation-based Taylor rule, a CPI-based Taylor rule, and an exchange rate peg. Also, the analysis shows the presence of a trade-off between stabilizing the output gap and domestic inflation on one hand and the nominal exchange rate and the terms of trade, on the other. They demonstrate that a policy of domestic inflation targeting, which simultaneously stabilizes both domestic prices and the output gap, requires larger volatility of the nominal exchange rate and the terms of trade relative to the simple Taylor rules or an exchange rate peg.



On the contrary Benigno and Benigno (2003) argue that the literature which suggests a similar optimal monetary policy prescription between an open economy and a closed economy to implement the flexible-price allocation depend on the assumption that the elasticity of substitution between domestic and foreign goods is unity. Still, policy makers may implement the flexible-price allocation under special restrictions on the structural parameters only, for instance in cases where the bias to inflate (associated with monopolistic competition) exactly offsets the deflationary bias (to manipulate the terms of trade in one's favour). They contend that in a more general preference specifications, even a policy maker operating under commitment or discretion will have an incentive to depart from implementing the flexible-price allocation. They attribute this to the fact that in the open-economy, a policy maker may have either an inflationary or deflationary bias.

To derive the results they use a model where markets are complete, nominal rigidities are in the form of one-period price contract, and prices are set in the currency of the producer. Also, they suggest that monetary policy coordination may bring efficiency. Sutherland (2002a) correspondingly shows that when monetary policy is coordinated, the welfare arising from international risk-sharing is relatively higher than the welfare level when there is no risk-sharing in the financial markets. His paper uses an approximation method to address the welfare analysis when the elasticity of substitution is different from unity.

Smelts and Wouters (2002) argue that optimal monetary policy should take into account the exchange rate volatility. They show that the central bank should aim at minimizing a weighted average of the domestic and import price inflation, in order to minimise the resource costs associated with the staggered price setting. Their paper examines the effects of imperfect exchange rate pass through for optimal monetary policy in a linearized open-economy dynamic general equilibrium model calibrated to euro area data. Imperfect exchange rate pass through is modelled as sticky import price behaviour. They estimate the degree of domestic and import price stickiness by reproducing the empirical impulse response of a monetary policy and exchange rate shock conditional on

the response of output, net trade and the exchange rate. Similarly, De Paoli (2009) says that the optimal monetary policy in a small open economy is not isomorphic to a closed economy. She shows that under a general specification and where the steady state of output is inefficient, the optimal monetary policy is the exchange rate targeting. She describes welfare in a small open economy and assumes that the utility-based loss function in a small open economy is a quadratic expression in the real exchange rate, output gap and domestic inflation. Domestic inflation targeting (price stability) is optimal only under a particular parameterization, and where price stickiness is the only distortion in the economy.

The common feature between all the studies reviewed in this chapter is their use of a welfare based method of evaluation. In a theoretical model it is relatively easy to include the cost push shock in the analysis of optimal policy rule. Practically however, the welfare maximising strategy becomes difficult and complex to implement. This is true even in the case where the loss function is simple. The optimal policy may entail responding to variables which cannot be measured or observed. Thus the monetary authority might find it impractical to follow an optimal policy. In this case it may be helpful to evaluate the performance of simple targeting and instrument rules using impulse response functions and volatility analysis. This is the aim of this chapter as well as point of departure from similar papers.

I build on Galí and Monacelli (2008<sup>12</sup>) who use a small open economy. I extend their model by including a cost push shock and a world output shock. Furthermore, I broaden the analysis by comparing how the results compares in the Clarida, Galí and Gertler (1998), rules commonly known as the CGG(+1) and the CGG(+4) rules. The forward-looking instrument rules tend to capture the behaviour of most central banks quite well. For instance, Svensson (2000) recommends that in an attempt to control inflation a few years ahead, central banks had to adopt forward looking rules. Moreover, instrument rules in which the policy rate is restricted to respond only to the deviations of

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<sup>12</sup> The monetary policy rules in particular the domestic inflation targeting and the consumer price inflation targeting rules were derived from Galí and Monacelli (2002).

the variables to their target level and lagged interest rate or past variables as specified in Chapter 2 are meant for a closed economy such as USA (Svensson, 1998). Thus, I consider Forward looking rules given that I am modelling a small open economy. In the next section I present the model used in the analysis of monetary policy rules in the presence of a cost push shock.

### 3.1 The Model.

Here I present a model for a small open economy characterised by complete asset markets, where both domestic and foreign goods are consumed; even though all goods can be traded internationally. There is no international coordination between this economy and the world economy. The world economy consists of a continuum of small open economies similar to the one modelled here, represented by the unit interval. Given that each small economy is of measure zero, its performance does not have any impact on the rest of the world. It is assumed here that different economies have identical preferences, technology and market structure, however they are subjected to imperfectly correlated productivity shocks. Firms are identical across countries with a constant return to scale.

In the next section I present the demand side of the model for a small open economy. Specifically, I present the preferences of the representative household, the composite consumption index, the domestic and imported goods indexes, the domestic and foreign inflation indexes, the overall consumer price index (CPI). The budget constraint faced by the household, the optimality conditions and their log-linearization is also shown.

#### 3.1.1 Household Preference.

A household is assumed to maximize the following utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\eta}}{1+\eta} \right]. \quad (3.1)$$

The consumer obtains utility from consumption  $C_t$  and receives disutility from work, represented by working hours  $N_t$ .  $\sigma$  stands for the elasticity of intertemporal substitution while  $\eta$  denotes the elasticity of labor supply, capturing the sensitivity of employment/labor supply to changes in the wage.  $E_0$  is the expectation as at time 0 while  $\beta^t$  is the intertemporal discount factor  $0 < \beta < 1$ .  $C_t$  is a composite consumption index as:

$$C_t \equiv \left[ (1-\alpha)^{\frac{1}{\nu}} \left( C_{H,t} \right)^{\frac{\nu-1}{\nu}} + \alpha^{\frac{1}{\nu}} \left( C_{F,t} \right)^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}}, \quad (3.1)$$

where  $C_{H,t}$  denotes the consumption basket of home produced goods,  $C_{F,t}$  stand for the consumption basket of foreign produced good but in the domestic economy.  $\nu > 0$  denotes the degree of substitution between domestic foreign and domestic goods respectively. In this model  $\nu$  is finite, i.e. the two goods are imperfect substitute of each other. An infinite  $\nu$  implies that the goods are perfect substitutes.  $\alpha > 0$  represents the bias towards the consumption of the home produced goods and thus a measures the openness of the economy.  $C_{H,t}$  is an index of consumption of domestic goods, which is given by the (constant elasticity of substitution) CES-function,  $C_{F,t}$  is similarly an index of consumption of imported goods, also characterised by the CES-function.

$$C_{H,t} \equiv \left[ \int_0^1 C_{H,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad C_{F,t} \equiv \left[ \int_0^1 C_{i,t}(j)^{\frac{\gamma-1}{\gamma}} di \right]^{\frac{\gamma}{\gamma-1}}, \quad (3.1)$$

where  $j$  represent a variety of goods,  $C_{i,t}$  is an index of the different goods imported from country  $i$  characterised by a CES-function, while  $\gamma$  denotes the elasticity of substitution between imported goods produced in different countries.  $\varepsilon > 1$  measure the elasticity of substitution between goods produced within an economy.

$$C_{i,t} \equiv \left[ \int_0^1 C_{i,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (3.1.4)$$

The domestic and foreign price indexes are given as:

$$P_{H,t} \equiv \left[ \int_0^1 P_{H,t}(j)^{1-\varepsilon} dj \right]^{\frac{1}{1-\varepsilon}} \quad P_{i,t} \equiv \left[ \int_0^1 P_{i,t}(j)^{1-\varepsilon} dj \right]^{\frac{1}{1-\varepsilon}} \quad (3.1.5)$$

For all  $i, j \in [0,1]$ , where  $P_{H,t}$  denotes the domestic price index, given by the CES-function,  $P_{i,t}$  is a CES-aggregator or price index of goods imported from country  $i$ . The consumer problem is to maximise total expenditure on home produced goods as well as foreign produced goods<sup>13</sup>. The ensuing demand functions for each category of goods are:

$$C_{H,t}(j) = \left( \frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\varepsilon} C_{H,t} \quad C_{i,t}(j) = \left( \frac{P_{i,t}(j)}{P_{i,t}} \right)^{-\varepsilon} C_{i,t} \quad (3.1.6)$$

The demand for good  $j$  is inversely related to its price relative to other goods and total demand. The optimal allocation of expenditures on imports by country of origin can be presented as:

$$C_{i,t} = \left( \frac{P_{i,t}}{P_{F,t}} \right)^{-\gamma} C_{F,t}. \quad (3.1.7)$$

For all  $i \in [0,1]$  and where  $P_{F,t} \equiv \left( \int_0^1 P_{i,t}^{1-\gamma} di \right)^{\frac{1}{1-\gamma}}$  denotes the price index of imported goods in terms of the domestic currency. The total expenditure on foreign goods can be expressed as:  $P_{F,t} C_{F,t}$ . Thus, total expenditure on both home and foreign goods can be expressed as:

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<sup>13</sup>Appendix (E).

$$\int_0^1 P_{H,t}(j) C_{H,t}(j) d_j + \int_0^1 \int_0^1 P_{i,t}(j) C_{i,t}(j) dj di = P_{H,t} C_{H,t} + P_{i,t} C_{i,t}, \quad (3.1.8)$$

$$P_t C_t = P_{H,t} C_{H,t} + P_{F,t} C_{F,t}. \quad (3.1.9)$$

The optimal allocation of expenditure between domestic and foreign goods can be written as<sup>14</sup>:

$$C_{H,t} = (1-\alpha) \left( \frac{P_{H,t}}{P_t} \right)^{-\nu} C_t, \quad C_{F,t} = \alpha \left( \frac{P_{F,t}}{P_t} \right)^{-\nu} C_t, \quad (3.1.10)$$

where  $P_t$  is the overall consumer price index (CPI) i.e. weighted average of both the domestic and foreign prices, expressed as:

$$P_t \equiv \left[ (1-\alpha) P_{H,t}^{1-\nu} + (\alpha) P_{F,t}^{1-\nu} \right]^{\frac{1}{1-\nu}}. \quad (3.1.11)$$

The budget constraint is given by:

$$P_t C_t + E_t \{ Q_{t,t+1} D_{t+1} \} \leq D_t + W_t N_t + T_t, \quad (3.1.12)$$

where  $Q_{t,t+1}$  is the stochastic discount factor for the one-period-ahead nominal payoffs relevant to the domestic household.  $D_{t+1}$  is the nominal payoff on the bond in the period  $t+1$  for the from a portfolio of assets held at the end of period  $t$ .  $W_t$  is the nominal wage,  $T_t$  is tax. The optimality condition is given by:

$$C_t^\sigma N_t^\eta = \frac{W_t}{P_t}. \quad (3.1.13)$$

The consumption Euler equation

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<sup>14</sup> Appendix (F).

$$\beta R_t E_t \left\{ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \left( \frac{P_t}{P_{t+1}} \right) \right\}. \quad (3.1.14)$$

$R_t = \frac{1}{Q_{t+1}}$  is the gross return on a riskless one period discount bond which pays one unit of the domestic currency in the next period  $t+1$ . The optimal conditions can be log-linearized as:

$$\sigma c_t + \eta n_t = w_t - p_t. \quad (3.1.1)$$

$$c_t = E_t c_{t+1} - \frac{1}{\sigma} [i_t - E_t \pi_{t+1} - \rho]. \quad (3.1.1)$$

$\rho \equiv -\log \beta$  is the time discount rate.

After presenting the household preferences, I now present how the domestic inflation is linked to the consumer price inflation (CPI), the real exchange rate and the terms of trade.

### 3.1.2 The Link between Domestic Inflation, CPI Inflation, Real Exchange Rate and Terms of Trade.

The bilateral terms of trade between the domestic economy and country  $i$  is defined as the price of country  $i$ 's goods in terms of the home goods:

$$S_{i,t} \equiv \frac{P_{i,t}}{P_{H,t}}. \quad (3.1.1)$$

The effective (multilateral) terms of trade are therefore:

$$S_t = \frac{P_{F,t}}{P_{H,t}}. \quad (3.1.1)$$

$$S_t = \frac{P_{F,t}}{P_{H,t}} = \left( \int_0^1 S_{i,t}^{1-\gamma} di \right)^{\frac{1}{1-\gamma}}.$$

$$1 + \ln s_t = 1 + \ln \left( \int_0^1 S_{i,t}^{1-\gamma} di \right)^{\frac{1}{1-\gamma}}.$$

$$1 + s_t = 1 + \left( \int_0^1 (1 - \gamma) S_{i,t} di \right)^{\frac{1}{1-\gamma}}$$

$$s_t = \int_0^1 S_{i,t} di. \quad (3.1.1)$$

Log-linearize equation (3.1.11) around the steady state<sup>15</sup>.

$$p_t = p_{H,t} + \alpha s_t. \quad (3.1.20)$$

where  $s_t = p_{F,t} - p_{H,t}$  represent the log effective terms of trade, or the price of foreign produced goods in terms of home produced goods. The first difference of (3.1.20) is given by:

$$\pi_t = \pi_{H,t} + \alpha \Delta s_t, \quad (3.1.21)$$

which states that domestic inflation and CPI inflation are linked by the changes in the terms of trade. Assuming that the law of one price holds<sup>16</sup> between imports and exports such that  $P_{i,t}(j) = e_{i,t} P_{i,t}^i(j)$  for all  $i, j \in [0,1]$ ; where  $e_{i,t}$  is the nominal exchange rate; the price of country  $i$ 's currency in terms of the domestic currency.  $P_{i,t}^i(j)$  is the price of good  $j$  imported and expressed in the currency of country  $i$ . Thus,  $P_{i,t} = e_{i,t} P_{i,t}^i$  where:

<sup>15</sup> Appendix (G).

<sup>16</sup> The price of a good is the same once converted into the same currency.



$$\begin{aligned}
P_{i,t}^i &\equiv \left[ \int_0^1 P_{i,t}^i(j)^{1-\varepsilon} dj \right]^{\frac{1}{1-\varepsilon}}, \\
P_{F,t} &= \left[ \int_0^1 P_{i,t}^i(j)^{1-\varepsilon} dj \right]^{\frac{1}{1-\varepsilon}}, \\
P_{F,t} &= \left[ \int_0^1 e_{i,t} P_{i,t}^i(j)^{1-\varepsilon} dj \right]^{\frac{1}{1-\varepsilon}}, \\
1 + \ln P_{F,t} &= 1 + \ln \int_0^1 \left[ e_{i,t} P_{i,t}^i(j)^{1-\varepsilon} dj \right]^{\frac{1}{1-\varepsilon}}, \\
p_{F,t} &= e_t + p_t^* \tag{3.1.2}
\end{aligned}$$

where  $e_t \equiv \int_0^1 e_{i,t} dj$  is the log nominal effective exchange rate and  $p_t^* = \int_0^1 p_{i,t}^i(j) dj$  is the log domestic price index for country  $i$  (in terms of its own currency) and where  $p_t^* = \int_0^1 p_{i,t}^i di$  represents the log world price index.

Combining (3.1.22) with the log of (3.1.18) we derive.

$$\begin{aligned}
e_t + p_t^* - p_{F,t} &= s_t - p_{F,t} + p_{H,t}, \\
e_t + p_t^* &= s_t + p_{H,t}, \\
e_t + p_t^* - p_{H,t} &= s_t, \\
s_t &= e_t + p_t^* - p_{H,t} \tag{3.1.23}
\end{aligned}$$

which states that the terms of trade is a linear function of the nominal exchange rate, the world price and the prices of domestically produced goods. Defining the bilateral exchange rate between the home country and country  $i$  as the ratio of the two countries' CPIs, but expressed in terms of the domestic currency as:

$$Q_{i,t} \equiv \frac{e_{i,t} p_t^i}{p_t} \tag{3.1.24}$$

Taking logs

$$q_{it} = e_{i,t} + p_t^i - p_t \quad (3.1.2)$$

The log effective real exchange rate is<sup>17</sup>:

$$q_t \equiv \int_0^1 q_{i,t} di \quad (3.1.2)$$

$$= \int_0^1 (e_{i,t} + p_t^i - p_t) di$$

$$= s_t + p_{H,t} - p_t$$

$$q_t = (1 - \alpha) s_t. \quad (3.1.2)$$

### 3.1.3 International Risk Sharing.

The international financial markets are complete and there is perfect capital mobility. Therefore, domestic residents can purchase either domestically or foreign denominated bonds, a condition which prevails to foreign residents as well. Schmitt-Grohe and Uribe (2003) states that models with either incomplete or complete markets give similar dynamics at business cycle frequencies. Therefore, the choice between complete or incomplete assets assumption should rather be dictated by the convenience of computation. The complete market assumption and the perfect capital mobility leads two results namely international risk sharing and uncovered interest parity condition. Consequently, the expected nominal returns on bonds will be the same in each country as follows:

$$R_t = R_t^i E_t \left( \frac{e_t^i}{e_{t+1}^i} \right) \quad (3.1.28)$$

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<sup>17</sup> Appendix (G).

To derive the international risk sharing we assume that the Euler equation of the foreign economy is assumed to be:

$$\beta R_t^i E_t \left\{ \left( \frac{c_{t+1}^i}{c_t^i} \right)^{-\sigma} \left( \frac{p_t^i}{p_{t+1}^i} \right) E_t \left( \frac{e_t^i}{e_{t+1}^i} \right) \right\} \quad (3.1.29)$$

Combining (3.1.29) with (3.1.14) and substituting for the real exchange rate<sup>18</sup>

$$\beta E_t \left\{ \left( \frac{c_{t+1}}{c_t} \right)^{-\sigma} \left( \frac{p_t}{p_{t+1}} \right) \right\} = \beta E_t \left\{ \left( \frac{c_{t+1}^i}{c_t^i} \right)^{-\sigma} \left( \frac{p_t^i}{p_{t+1}^i} \right) E_t \left( \frac{e_t^i}{e_{t+1}^i} \right) \right\} \quad (3.1.30)$$

$$C_t = \mathcal{G} C_t^i Q_{i,t}^{\frac{1}{\sigma}} \quad (3.1.31)$$

where  $\mathcal{G}^i = E_t \left( \frac{C_{t+1}^i}{C_{t+1} Q_{i,t}^{\frac{1}{\sigma}}} \right)$  is a constant which depends on the initial foreign assets

position. Assuming a zero net foreign asset holding, and an ex-ante identical environment:  $\mathcal{G}^i = \mathcal{G} = 1 \forall i$ . Thus taking logs of both sides of (3.1.31) yields<sup>19</sup>:

$$c_t = c_t^i + \frac{1}{\sigma} q_{i,t} \quad (3.1.32)$$

$$c_t = c_t^* + \left( \frac{1-\alpha}{\sigma} \right) s_t. \quad (3.1.33)$$

The home consumption is related to the world consumption through the terms of trade.

### 3.1.4 Uncovered Interest Parity and the Terms of Trade.

The complete international financial markets assumption implies that the equilibrium price of a riskless bond denominated in the currency of country  $i$  is given by

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<sup>18</sup> Appendix (H).

<sup>19</sup> Appendix (H).

$e_{i,t}Q_t^i = E_t \{Q_{t,t+1}e_{i,t+1}\}$ . The equation for the domestic bond price is stated as:  $Q_t = E_t \{Q_{t,t+1}\}$ , where  $Q_t^i$  denotes the price of the bond expressed in the currency of country  $i$ . Combining the two expressions yields the uncovered interest parity as follows<sup>20</sup>

$$E_t \{Q_{t,t+1}[(Q_t - Q_t^i)e_{i,t+1} - e_{i,t}]\} = 0 \quad (3.1.3)$$

Taking logs on both sides and aggregating over  $i$ .

$$i_t = i_t^* + E_t \{\Delta e_{t+1}\}, \quad (3.1.3)$$

which is the uncovered interest parity condition stating that domestic interest rate is a function of world interest rate and the expected appreciation of the nominal exchange rate of the domestic currency. Combining (3.1.23) with (3.1.35) we get:

$$E_t s_{t+1} - s_t = E_t e_{t+1} - e_t + E_t P_{t+1}^* - P_t^* - E_t P_{H,t+1} - P_{H,t} \quad (3.1.36)$$

$$s_t = (i_t^* - E_t \{\pi_{t+1}^*\}) - (i_t - E_t \{\pi_{t+1}\}) + E_t \{s_{t+1}\} \quad (3.1.3)$$

The terms of trade of trade are pinned down in a perfect foresight steady state. It follows that  $\lim_{T \rightarrow \infty} E_t \{S_T\} = 0$ . Solving forward we get:

$$s_t = E_k \left\{ \sum_{k=0}^{\infty} [(i_{t+k}^* - \pi_{t+k}^*) - (i_{t+k} - \pi_{t+k})] \right\} \quad (3.1.3)$$

The terms of trade are an expected sum of the real interest rate differential between the home market and the world market.

### 3.2 Firms

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<sup>20</sup> Appendix (H).

In the ensuing section I present the production side of the model. More precisely, I present the production technology of the firm. I also describe the price setting behavior of the firms and present the optimal price for the optimizing firm.

### 3.2.1 Production Technology

Each country has a continuum of monopolistic firms, each firm produces a differentiated good  $j$ . A firm in the domestic economy produces a differentiated good with a linear technology represented by the production function:

$$Y_t(j) = A_t N_t(j) \quad (3.1.3)$$

where  $a_t = \rho_a a_{t-1} + \xi_t$ ; and where  $j \in [0,1]$  stand for a firm-specific index. The real marginal cost in terms of domestic prices is assumed to be common across domestic firms and given by:

$$mc_t = -o + w_t - p_{H,t} - a_t, \quad (3.1.40)$$

where  $o \equiv \log(1-\tau)$ , while  $\tau$  is an employment subsidy.

### 3.2.2 Price Setting Behavior of the firm

A representative firm set the price of its produce to maximise profit. In the domestic economy, firms set prices in a Calvo (1983) fashion. Consequently, prices are staggered; creating rigidities in the economy. According to the Calvo pricing strategy only a fraction  $1-\omega$  of domestic firms are able to change the prices of their production. The remaining fraction of firms  $\omega$  maintain their prices unchanged. The aggregate domestic price level is therefore a combination of two factions of firms, optimising firms  $(1-\omega_H)$  and non-optimising firms  $(\omega_H)$  as shown in (3.1.41) below.

$$P_{H,t} = \left[ (1 - \omega_H) \bar{P}_{H,t}^{1-\nu} + \omega_H P_{H,t-1}^{1-\nu} \right]^{\frac{1}{1-\nu}}, \quad (3.1.41)$$

where  $\bar{P}_{H,t}$  is the price of optimising firms while  $P_{H,t-1}$  is the price level of firms which do not adjust their prices. Log-linearizing (3.1.41) becomes<sup>21</sup>:

$$p_{H,t} = (1 - \omega_H) (\bar{p}_{H,t} - p_{H,t-1}). \quad (3.1.4)$$

An optimising firm ( $j$ ) chooses a new price  $\bar{P}_{H,t}$  to maximise the present value of its dividends:

$$\max_{P_{H,t}(j)} \sum_{k=0}^{\infty} \omega^k E_t \left\{ Q_{t,t+k} \left[ Y_{t+k}^d(j) (\bar{P}_{H,t}(j) - MC_{t+k}^n(j)) \right] \right\}, \quad (3.1.4)$$

subject to the budget constraints

$$Y_{t+k}^d(j) \leq \left( \frac{\bar{P}_{H,t}}{P_{H,t+k}} \right)^{-\varepsilon} \left( C_{H,t+k}(j) + \int_0^1 C_{i,t+k}(j) di \right) = \left( \frac{\bar{P}_{H,t}}{P_{H,t+k}} \right)^{-\varepsilon} y_{t+k} \quad (3.1.44)$$

for  $k = 0, 1, 2$ , where  $\omega^k$  is the stochastic discount factor,  $MC_{t+k}^n$  is the marginal cost.

Thus  $(\bar{P}_{H,t} Y_{t+k}^d)$  is the total revenue; while  $(MC_{t+k}^n Y_{t+k}^d)$  are the total costs. The first order condition for the price optimisation can be written as<sup>22</sup>:

$$\sum_{k=0}^{\infty} \omega^k E_t \left\{ Q_{t,t+k} Y_{t+k}^d \left[ \bar{P}_{H,t} - \frac{\varepsilon}{\varepsilon - 1} MC_{t+k}^n Y_{t+k}^d \right] \right\} = 0 \quad (3.1.4)$$

where,  $\left( \frac{\varepsilon}{\varepsilon - 1} \right)$  stands for the mark-up over the marginal costs. Log-linearizing

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<sup>21</sup> Appendix (I).

<sup>22</sup> Appendix (I).

(3.1.45) around the steady state inflation yields:

$$\bar{p}_{H,t} = (1 - \beta\omega_H) E_t \sum_{k=0}^{\infty} (\beta\omega_H)^k mc_{t+k} + P_{H,t+k}. \quad (3.1.4)$$

A firm sets the price as a mark-up over a weighted average of the expected future marginal costs. The optimal price setting of firms yields a rule for the development of the domestic inflation.

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \lambda_H mc_t, \quad (3.1.4)$$

where  $\lambda_H = \frac{(1 - \omega_H)(1 - \beta\omega_H)}{\omega}$

The domestic inflation is forward looking.

After describing the optimal price setting behaviour of the firm, in the next section, I present the goods market equilibrium conditions in a small open economy. It should be noted that unlike in the previous chapter, total consumption in a small economy comprises of the consumption of the domestic produced goods and the consumption of a foreign produced goods. This analysis culminates into the dynamic aggregate output equation in the small open economy. The section also presents the trade balance, the marginal cost and inflation dynamics. The later subsection also presents the link between the marginal costs, the terms of trade, world output and domestic output. The section ends with New Keynesian Phillips Curve augmented with the cost push shock intended to induce a trade-off which policy makers face when stabilising output or inflation. The rest of the section is presented below:

### 3.3 Equilibrium Conditions

#### 3.3.1 Aggregate Demand and Output Determination

##### 3.3.1.1 Consumption and Output

In equilibrium the domestic production  $Y_t$  of good  $(j)$  must be equal to domestic consumption  $C_{H,t}(j)$  and foreign consumption  $C_{H,t}^i(j)$ :

$$Y_t(j) = C_{H,t}(j) + \int_0^1 C_{H,t}^i(j) di. \quad (3.1.4)$$

Inserting (3.1.6), (3.1.7) and (3.1.10) into (3.1.4) yields<sup>23</sup>:

$$Y_t(j) = \left( \frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\varepsilon} (1-\alpha) \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} C_t + \int_0^1 \alpha \left( \frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\varepsilon} \left[ \frac{P_{H,t}}{\varepsilon_{i,t} P_{F,t}^i} \right]^{-\gamma} \left( \frac{P_{F,t}^i}{P_t^i} \right)^{-\nu} C_t^i di \quad (3.1.49)$$

Defining the aggregate domestic output as:  $Y_t \equiv \left[ \int_0^1 Y_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}}$ , we thus insert in (3.1.49).

$$Y_t \equiv \left[ \int_0^1 \left( \frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\varepsilon} \left\{ (1-\alpha) \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} C_t + \int_0^1 \alpha \left[ \frac{P_{H,t}}{\varepsilon_{i,t} P_{F,t}^i} \right]^{-\gamma} \left( \frac{P_{F,t}^i}{P_t^i} \right)^{-\nu} C_t^i di \right\}^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}},$$

$$Y_t \equiv \left[ (1-\alpha) \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} C_t + \alpha \int_0^1 \left[ \frac{P_{H,t}}{\varepsilon_{i,t} P_{F,t}^i} \right]^{-\gamma} \left( \frac{P_{F,t}^i}{P_t^i} \right)^{-\nu} C_t^i di \right] P_{H,t}^{\varepsilon} (P_{H,t}^{1-\varepsilon})^{\frac{\varepsilon}{\varepsilon-1}},$$

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<sup>23</sup> Appendix (J).



$$Y_t = \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} \left[ (1-\alpha)C_t + \alpha \int_0^1 \left[ \frac{\varepsilon_{i,t} P_{F,t}^i}{P_{H,t}} \right]^{\gamma-\nu} \left( \frac{P_{F,t}^i}{P_t^i} \right)^{-\nu} C_t^i di \right].$$

The real exchange is defined as  $\left( \frac{\varepsilon_{i,t} P_{F,t}^i}{P_t^i} \right)$  which is equivalent of  $\left( \frac{P_{F,t}^i}{P_t^i} \right)$  but given that the CPI is instead for country ( $i$ ) thus the real exchange rate can be expressed as  $(Q_{i,t})^\nu$ .

$$Y_t = \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} \left[ (1-\alpha)C_t + \alpha \int_0^1 \left[ \frac{\varepsilon_{i,t} P_{F,t}^i}{P_{H,t}} \right]^{\gamma-\nu} (Q_{i,t})^\nu C_t^i di \right] \quad (3.1.5)$$

Substitute  $(S_{i,t})$  for the bilateral terms of trade  $\left( \frac{P_{F,t}^i}{P_{H,t}} \right)$  and  $(S_t^i)$  for the effective terms of trade  $\left( \frac{\varepsilon_{i,t}}{P_{H,t}} \right)$ .  $Y_t$  becomes:

$$Y_t = \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} \left[ (1-\alpha)C_t + \alpha \int_0^1 [S_t^i S_{i,t}]^{\gamma-\nu} (Q_{i,t})^\nu C_t^i di \right],$$

$$Y_t = \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} \left[ (1-\alpha)C_t + \alpha \int_0^1 [S_t^i S_{i,t}]^{\gamma-\nu} (Q_{i,t})^\nu (Q_{i,t})^{-\frac{1}{\sigma}} C_t^i di \right],$$

$$Y_t = \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} C_t \left[ (1-\alpha) + \alpha \int_0^1 [S_t^i S_{i,t}]^{\gamma-\nu} (Q_{i,t})^{\nu-\frac{1}{\sigma}} di \right],$$

$$Y_t = \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} C_t \left[ (1-\alpha) + \alpha \int_0^1 [S_t^i S_{i,t}]^{\gamma-\nu} (Q_{i,t})^{\nu-\frac{1}{\sigma}} di \right]. \quad (3.1.6)$$

Log- linearizing (3.1.6) around the steady state gives:

$$y_t = c_t + \frac{\alpha\varpi}{\sigma} s_t, \quad (3.1.7)$$

where  $\varpi \equiv \sigma\gamma + (1-\alpha)(\sigma\nu-1)$ ,  $\frac{\alpha\varpi}{\sigma} s_t$  are the terms of trade effect.

For a generic country  $i$ , (3.1.52) can be written as  $y_t^i = c_t^i + \frac{\alpha\varpi}{\sigma} s_t^i$ .

Aggregating over all countries we derive the world market clearing condition.

$$y_t^* \equiv \int_0^1 y_t^i di = \int_0^1 \left( c_t^i + \frac{\alpha\varpi}{\sigma} s_t^i \right) di = \int_0^1 c_t^i di + \frac{\alpha\varpi}{\sigma} \int_0^1 s_t^i di = \int_0^1 c_t^i di \equiv c_t^*. \quad (3.1.53)$$

(3.1.53) is derived by assuming that  $\int_0^1 s_t^i di \equiv 0$ , and where  $y_t^*$  and  $c_t^*$  are world output and consumption indexes expressed in log terms. Combining the domestic goods market equilibrium condition (3.1.52) with the international risk sharing (3.1.33) and substituting for the world output condition (3.1.53), the aggregate output condition in terms of world output can therefore be written as:

$$y_t = c_t^* + \frac{1-\alpha}{\sigma} s_t + \frac{\alpha\varpi}{\sigma} s_t, \quad (3.1.54)$$

$$y_t = y_t^* + \frac{1}{\sigma_\alpha} s_t, \quad (3.1.55)$$

$$\sigma_\alpha \equiv \frac{\sigma}{1+\alpha(\varpi-1)}. \quad (3.1.56)$$

Combining (3.1.56) with the consumption Euler equation (3.1.16), and the terms of trade (3.1.21) we derive the dynamic aggregate output equation.

$$y_t = E_t y_{t+1} - \frac{1}{\sigma} (i_t - E_t \pi_{t+1} - \rho) - \frac{\alpha\varpi}{\sigma} \Delta E_t s_{t+1} \quad (3.1.57)$$

$$y_t = E_t y_{t+1} - \frac{1}{\sigma} (i_t - E_t \pi_{t+1} - \rho) - \frac{\Theta}{\sigma} \Delta E_t s_{t+1} \quad (3.1.58)$$

$$\Theta = \sigma\gamma - 1 + (1-\alpha)(\sigma\nu-1)$$

$$y_t = E_t y_{t+1} - \frac{1}{\sigma_\alpha} (i_t - E_t \pi_{H,t+1} - \rho) + \alpha \Theta \Delta E_t y_{t+1}^* \quad (3.1.5)$$

where  $\Theta = \omega - 1$ .

This implies that the degree of openness as expressed by  $(\sigma_\alpha)$  has an influence on the sensitivity of domestic output to changes resulting from the real interest rate.

### 3.3.1.2 The Trade Balance

We define the net exports as the difference between total production and total consumption in relation to the steady state output  $Y$ :

$$nx_t \equiv \frac{Y_t - \frac{P_t}{P_{H,t}} C_t}{Y}. \quad (3.1.6)$$

A first order approximation around a symmetric steady state:

$$nx_t = \frac{Y_t - Y}{Y} - \frac{C_t - C}{C} - \frac{P_t - P}{P} + \frac{P_{H,t} - P}{P}, \quad (3.1.7)$$

$$nx_t = y_t - c_t - p_t + p_{H,t}, \quad (3.1.8)$$

$$nx_t = y_t - c_t - \alpha s_t \quad (3.1.63)$$

Substituting  $y_t - c_t$  in equation (3.1.63) with (3.1.52)

$$nx_t = \frac{\alpha \varpi}{\sigma} s_t - \alpha s_t, \quad (3.1.9)$$

$$nx_t = \alpha \left( \frac{\varpi}{\sigma} - 1 \right) s_t. \quad (3.1.65)$$

### 3.3.2 Marginal Cost and Inflation Dynamics

#### 3.3.2.1 Aggregate Output and Employment

The relation between employment, technology and output can be written as<sup>24</sup>:

$$y_t = a_t + n_t. \quad (3.1.66)$$

The marginal cost and inflation dynamics is given by:

$$mc_t = -o + w_t - p_{H,t} - a_t. \quad (3.1.67)$$

Inserting the log-linearized FOC of the household's optimising expressed as the intratemporal consumption (3.1.15) as well as the adjusted formula for the terms of trade<sup>25</sup> (3.1.20) into (3.1.67).

$$mc_t = -o + \sigma y_t^* + \eta y_t + s_t - (1 - \eta) a_t. \quad (3.1.68)$$

The marginal cost is an increasing function of the terms of trade and world output. The real wage is influenced through the wealth effect on labor supply as a result of the impact of these variables on domestic consumption. Changes in the terms of trade have a direct effect on the product wage for any given level of consumption wage. Technology has direct effect on labor productivity. Domestic output has an effect on employment as well as the real wage for a given output. Substituting for the terms of trade term, we derive:

$$mc_t = -o + (\sigma_\alpha + \eta) y_t + (\sigma - \sigma_\alpha) y_t^* - (1 + \eta) a_t. \quad (3.1.69)$$

Domestic output affects the marginal costs through its resultant impact on employment ( $\eta$ ) the terms of trade given by ( $\sigma_\alpha$ ). On the other hand, world output also affects the

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<sup>24</sup> Appendix (J).

<sup>25</sup> Appendix (J).

marginal costs through its effect on consumption; captured by  $(\sigma)$  and the terms of trade of trade  $(\sigma_\alpha)$ . The sign of the impact is however ambiguous. In case where  $(\sigma > \sigma_\alpha)$ , the impact of the world output on marginal cost will tend to be positive. From (3.1.69) the natural output can be written as<sup>26</sup>:

$$m_C = -\mu = -\phi + (\sigma_\alpha + \eta) y_t^n + (\sigma - \sigma_\alpha) y_t^* - (1 - \eta) a_t, \quad (3.1.7)$$

$$y_t^n = \Gamma_0 + \Gamma_a a_t + \Gamma_* y_t^*, \quad (3.1.7)$$

$$\text{where, } \Gamma_0 \equiv \frac{\nu - \mu}{\sigma_\alpha + \eta}, \Gamma_a \equiv \frac{1 - \eta}{\sigma_\alpha + \eta} a_t > 0, \Gamma_* \equiv -\frac{\alpha \Theta \sigma_\alpha}{\sigma_\alpha + \eta} y_t^*$$

### 3.3.2.2 The New Keynesian Phillips Curve

Inserting the real marginal cost gap into (3.1.47) we derive the New Keynesian Phillips curve<sup>27</sup>:

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \kappa_\alpha \tilde{y}_t, \quad (3.1.7)$$

$$\text{where } \kappa_\alpha = \lambda_H (\sigma_\alpha + \eta)$$

The implication of (3.1.72) is that there is no short run trade-off between stabilizing the output gap and inflation. Blanchard and Galí (2007) term the above phenomenon as the divine coincidence. Fuhrer and Moore (1995) argue that in the New Phillips curve, as represented in (3.1.72) inflation should lead output over the cycle. A rise in current inflation indicates that output will rise in the subsequent period and vice-versa and that a disinflation policy should be cost less. This is in sharp contrast to Ball (1993 and 1994b)

<sup>26</sup> Appendix (J).

<sup>27</sup> Appendix F

who argues that a disinflation is costly. To capture the trade-off between inflation and the output gap, we introduce an exogenous cost push shock similar to Clarida et al (1999, 2002). This changes equations (3.1.13) to become:

$$(1 + \mu_t^w)(C_t)^\sigma (N_t)^\eta = \frac{W_t}{P_t}, \quad (3.1.73)$$

where  $\mu_t^w$  is assumed to follow an AR(1) process  $\mu_t^w = \rho_w \mu_{t-1}^w + \xi_t$ . Clarida et al (1999, 2002) states that the shock stands for any variations that may affect the marginal cost and consequently break the relationship between the marginal cost and the output gap. Taking logs both sides of (3.1.73) gives us:

$$\eta n_t + \sigma c_t + \mu_t^w = w_t - p_t, \quad (3.1.74)$$

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \kappa_\alpha \tilde{y}_t + u_t, \quad (3.1.75)$$

The above equation states that there is a trade-off between stabilizing inflation and the output gap as indicated by the cost push variable.

where  $u_t = (\sigma_\alpha + \eta) \mu_t^w$ .

### 3.3.2.3 The Dynamic IS equation

From (3.1.59), the IS equation can be written as<sup>28</sup>:

$$y_t = E_t y_{t+1} - \frac{1}{\sigma_\alpha} (r_t - \rho) + \alpha \Theta \Delta E_t y_{t+1}^*; \quad (3.1.76)$$

Defining the natural output as

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<sup>28</sup> Appendix (J).

$$y_t^n = E_t y_{t+1}^n - \frac{1}{\sigma_\alpha} (r_t^n - \rho) + \alpha \Theta \Delta E_t y_{t+1}^* \quad (3.1.7)$$

The output gap can be written as<sup>29</sup>:

$$\tilde{y}_t = E_t \tilde{y}_{t+1} - \frac{1}{\sigma_\alpha} (i_t - E_t \pi_{t+1} - r_t), \quad (3.1.7)$$

where the real rate ( $r_t$ ) is defined as:

$$r_t = \rho - \sigma_\alpha \Gamma_a (1 - \rho_\alpha) a_t + \sigma_\alpha + \frac{\alpha \Theta \sigma_\alpha \eta}{\sigma_\alpha + \eta} E_t \Delta y_{t+1}^* \quad (3.1.7)$$

To close the model I now present the monetary policy rule(s) of the central bank.

### 3.4 Monetary Policy Rules

$$\text{Domestic Inflation Targeting: } \pi_{H,t} = 0. \quad (3.1.8)$$

$$\text{Consumer Price Targeting: } P_t = 0. \quad (3.1.8)$$

$$\text{Fixed Exchange Rate(PEG): } e_t = 0. \quad (3.1.8)$$

$$\text{Taylor Rule: } i_t = \rho + \phi_\pi \pi_{H,t} + \phi_y \tilde{y}_t + v_t. \quad (3.1.8)$$

$$\text{CGG(+1)} \quad i_t = \rho + \phi_i i_{t-1} + (1 - \phi_i) [\phi_\pi \pi_{H,t} + \phi_y \tilde{y}_t] + v_t \quad (3.1.8)$$

$$\text{CGG(+4)} \quad i_t = \rho + \phi_i i_{t-4} + (1 - \phi_i) [\phi_\pi \pi_{H,t} + \phi_y \tilde{y}_t] + v_t \quad (3.1.8)$$

where  $i_t$  stands for the interest rate of the central bank,  $v_t$  represent the shock to the interest rate. It is assumed,  $v_t$  follows an AR(1) process  $v_t = \rho_v v_{t-1} + \varepsilon_t^v$ . The parameters  $\phi_\pi$ ,  $\phi_y$  and  $\phi_r$  are coefficients of inflation, output and interest rate respectively.

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<sup>29</sup> Appendix F.

### 3.5 The foreign economy

The foreign economy is assumed to be exogenous to the small open economy. It is described by one equation:

$$y_t^* = \rho_{yx} y_{t-1}^* + \xi_t^{y^*} \quad (3.1.8)$$

For  $t = 0, 1, 2, \dots$ . The developments of the foreign output is described by an AR(1) process for  $0 < \rho_{yx} < 1$  and the production shock  $\xi_t^{y^*}$ .

### 3.6 Linearized model

The complete model can be presented by 7 endogenous variables and three shocks given as:

$$1. \text{ Domestic Inflation: } \pi_{H,t} = \beta E_t \{ \pi_{H,t+1} \} + \kappa_\alpha \tilde{y}_t + u_t. \quad (3.1.75)$$

$$2. \text{ Output gap: } \tilde{y}_t = E_t \{ \tilde{y}_{t+1} \} - \frac{1}{\sigma_\alpha} (i_t - E_t \{ \pi_{t+1} \} - r_t^n). \quad (3.1.78)$$

$$3. \text{ Real interest rate: } r_t = \rho - \sigma_\alpha \Gamma_\alpha (1 - \rho_\alpha) a_t + \sigma_\alpha + \frac{\alpha \sigma_\alpha \eta}{\sigma_\alpha + \eta} E_t \Delta y_{t+1}^*. \quad (3.1.79)$$

$$4. \text{ Real exchange rate: } q_t = (1 - \alpha) s_t. \quad (3.1.27)$$

$$5. \text{ Terms of Trade: } s_t = E_t \left\{ \sum_{k=0}^{\infty} \left[ (i_{t+k}^* - E_t \pi_{t+k}^*) - (i_{t+k} - E_t \pi_{t+k}) \right] \right\}. \quad (3.1.38)$$

$$6. \text{ CPI Inflation: } \pi_t = \pi_{H,t} + \alpha \Delta s_t \quad (3.1.21)$$

7. Policy rules:

$$\text{Domestic Inflation Targeting: } \tilde{y}_t = \pi_{H,t} = 0. \quad (3.1.8)$$

$$\text{Consumer Price Targeting: } P_t = 0. \quad (3.1.8)$$

$$\text{Fixed Exchange Rate(PEG): } e_t = 0. \quad (3.1.8)$$



$$\text{Taylor Rule:} \quad i_t = \rho + \phi_\pi \pi_{H,t} + \phi_y \tilde{y}_t. \quad (3.1.8)$$

$$\text{CGG(+1)} \quad i_t = \rho + \phi_i i_{t-1} + (1 - \phi_i) \left[ \phi_\pi \pi_{H,t} + \phi_y \tilde{y}_t \right] \quad (3.1.84)$$

$$\text{CGG(+4)} \quad i_t = \rho + \phi_i i_{t-1} + (1 - \phi_i) \left[ \phi_\pi \pi_{H,t+4} + \phi_y \tilde{y}_t \right] \quad (3.1.8)$$

$$8. \text{ Technology shock: } a_t = \rho_a a_{t-1} + \xi_t. \quad (3.1.3)$$

$$9. \text{ Cost push shock: } u_t = \rho_u u_{t-1} + \xi_t. \quad (3.1.7)$$

$$10. \text{ Foreign output shock: } y_t^* = \rho_{yx} y_{t-1}^* + \xi_t^*. \quad (3.1.8)$$

Having presented the linearised version of the small open economy model. I solve the model in Dynare version 4.2, using parameter values presented in table 2. In the next move I present the results of the model.

## 4 Results

In this section I present the results of the model. First I present and discuss the impulse response functions and the macroeconomic volatility of variables, and then I conclude.

### 4.1 Impulse response functions

Figure 3, shows the results of a positive innovation to technology/productivity under the three targeting rules, where the smooth line represent the DIT, the dotted line stand for the CIT and the lines with rectangular marks is the PEG. The domestic inflation and the output gap are constant in the DIT rule. The impulse of the output gap and inflation are very similar under the PEG and the CIT rules i.e. both variables decline in response to a positive shock in technology. The shock brings a persistent reduction in the nominal interest rate; which is required to support the expansion in output. The only difference between the CIT and DIT is the decline in the nominal interest rate which is instantaneous in the case of the latter and muted in the CIT.

Figure 4, depicts the impulse responses to a positive innovation in the cost push shock in the targeting rules. The shock causes a reduction in the output gap in all targeting rules. By construction, the domestic inflation is constant in the DIT while it increases in the CIT and PEG. The nominal interest rates increase to tame domestic inflation in the CIT and DIT. The only noticeable difference however is that, the increase in the nominal interest rate is inertial in the CIT. Figure 5, displays the impulse responses due to a positive innovation in the foreign output. Similar to the domestic technology, the output gap and domestic inflation is flat in the DIT rule. However, in the CIT and PEG both the output gap and the domestic inflation increase with the PEG displaying the significant increase. The nominal interest rate decreases in all the three policy rules.

Figure 6, shows the impulse responses to a technology shock under instrument rules. The line with rectangular marks is the Taylor rule, the line with the triangular marks stands for the CGG(+1) while the line with stars represent the CGG(+4). Accordingly, the innovation causes a decline in the output gap and the domestic inflation in all instrument rules this is similar to the CIT and PEG. The central bank engineers an increase in the interest rate in response to the decline in the output gap and domestic inflation. The only difference between the instrument rules is that the decline in both the output gap and domestic inflation is relatively bigger in the CGG(+4) and the CGG(+1) and smaller in the Taylor rule in the short run. This can be explained by the fact that in the Taylor type rule, the nominal and real interest rate increase less when contrasted to the CGG(+1) and CGG(+4).

Figure 7, presents the impulse responses to a positive innovation to the cost push shock. The reaction of the domestic inflation and output gap is similar to that of the targeting rules, i.e. the output gap decreases while inflation increases. In the CGG(+1) and CGG(+4) policy rules however, the output gap first increase before declining. This can be explained by the fact that the increase in the nominal interest rate is not adequate enough in the forward looking targeting rules compared to the Taylor rule as evident from the moderate increase in the nominal interest rate in the latter. Figure 8, displays the impulse responses due a positive innovation in the foreign output. The output gap and

domestic inflation decline in the CGG(+1) and CGG(+4) while they remain constant in the Taylor rule. This can be ascribed to the relatively small decrease in the nominal interest rate. The central bank reduces the nominal interest rates to increase consumption with a view that the output gap will pick up.

## **4.2 Macroeconomic volatility**

Table 3, contains the volatility of the various monetary rules due to a technology shock. The DIT seems to be the policy which simultaneously reduces the volatility of the output gap and domestic inflation. These results are however similar to the findings of Galí and Monacelli (2002) and Galí (2008). The CGG(+4) seems to increase the volatility of the output gap and domestic inflation the most. This is due to the fact that both the output gap and domestic inflation are much volatile in the CGG(+4) than in any other rule. Similar to Galí and Monacelli (2002) and Galí (2008), the PEG produces much volatility of the output gap and inflation. Given a fixed exchange rate, it is impossible for the monetary authority to lower the nominal interest rate or to allow the currency to depreciate in response to an increase in output. Consequently, the volatility of the output gap and domestic inflation tend to increase more in the PEG. Among instrument rules, the Taylor rule performs relatively better than both the CGG(+1) and CGG(+4).

This scenario can be accounted for by the fact that the forward looking rules respond to forecasted inflation, while the Taylor rule responds to contemporaneous inflation. Table 4, presents the volatilities of the various monetary policy rules in response to a cost push shock. Unlike in the case of a technology shock, there is no single policy which can stabilise the domestic inflation and the output gap simultaneously. The targeting rule displays the minimal volatility of the domestic inflation, with the DIT as the best performing rule. Similar to the technology shock, the volatility of the domestic inflation is very high in the CGG(+4). The CGG(+1), however shows the minimal volatility of the output gap, compared to all other rules.

Among the targeting rules, the PEG has the lowest volatility of the output gap. The volatility of the output gap appears to be very significant in the CGG(+4) than for any other rule. Thus the policy maker would face a dilemma between minimising domestic inflation or the output gap in the presence of a cost push shock. Accordingly a policy maker who is pro stabilising the domestic inflation would prefer the DIT to minimise the volatility of the domestic inflation at the expense of high volatility of the output gap. On the contrary, a policy maker who is pro output gap stabilisation would prefer the CGG(+1) which minimises the volatility of the outputgap, at the expense of high domestic inflation volatility.

Table 5, presents the volatilities following a foreign output shock. By construction the DIT shows the lowest volatility of the output gap and domestic inflation compared to any other rule. Among the targeting rules, the PEG shows relatively high volatility of the output gap and domestic inflation while the CIT is in the middle. In the CIT, the domestic inflation is not constant and hence explains the difference in volatility of the output gap and domestic inflation, compared to the DIT.

Domestic inflation is part of the CPI inflation; therefore by targeting consumer price inflation, the CIT rule tends to stabilize domestic inflation as well. For the PEG however, it is not possible to stabilize the CPI and this explains the high output gap and domestic inflation in the PEG in contrast to the CIT. Similar to the domestic technology shock and cost push shock the CGG(+4) exhibits a relatively high volatility of the domestic inflation and output gap compared to all other rules followed by the CGG(+1). Among the instrument rules, the Taylor rule displays the lowest volatility of the output gap and domestic inflation.

In terms of rankings the DIT is superior when the economy is hit by a technology shock or foreign output shock. Thus, the DIT would be preferred among all other rules considered. The PEG would be inferior among the targeting rules. Among instrument rules, the Taylor rule is superior than the CGG(+1) and the CGG(+4) in terms of minimising the volatilities of both the domestic inflation and the output gap. When the economy is hit by a cost push shock the DIT is only superior in terms of stabilising the

domestic inflation, but at the expense of high output gap volatilities. The CGG(+1) emerges as the superior rule in terms of minimising the volatilities of the output gap.

### **4.3 Conclusion**

The aim of this chapter is to compare the performance of targeting rules and instrument rules given three shocks, technology shock, foreign output shock and a cost push shock. In particular, a comparison is made between the DIT, CIT, PEG, the Taylor (1993) and the forward looking rules CGG(+1) and the CGG(+4).

The chapter uses the impulse response function as well as the volatility of the output gap and domestic inflation as the yardstick of the evaluation. I show that the results of Galí and Monacelli (2002) and Galí (2008) that the DIT policy is superior in the presence of a technology shock, extends to a foreign output shock. The Taylor rule is superior compared to its forward looking counterparts. In the presence of a cost push shock the DIT is only superior in stabilizing the domestic inflation. The CGG(+1) becomes the best policy in minimising the volatilities of the output gap. The CGG(+4) tend to increase the volatility of the output gap and domestic inflation the most and thus is ranked as least desirable policy rule given this model and calibration.

The intuition of these results is that the central bank faces a policy dilemma as to which policy rules is superior in terms of stabilising both the output gap and domestic inflation. The dilemma is caused by the nature of the shock which hits the economy. When the shock is caused by a technology shock or foreign output, the policy maker would prefer the DIT rule. However, if the shock is caused by a cost push factor, the policy maker would prefer the DIT rule to stabilise the domestic inflation or the CGG(+1) to minimise the volatilities in the output gap. In practise however policy makers cannot alter policy rules with each shock hitting the economy and hence faces a policy dilemma in particular when faced with a cost push shock.

Figure 3 Impulse Responses to a Productivity Shock: Targeting Rules.

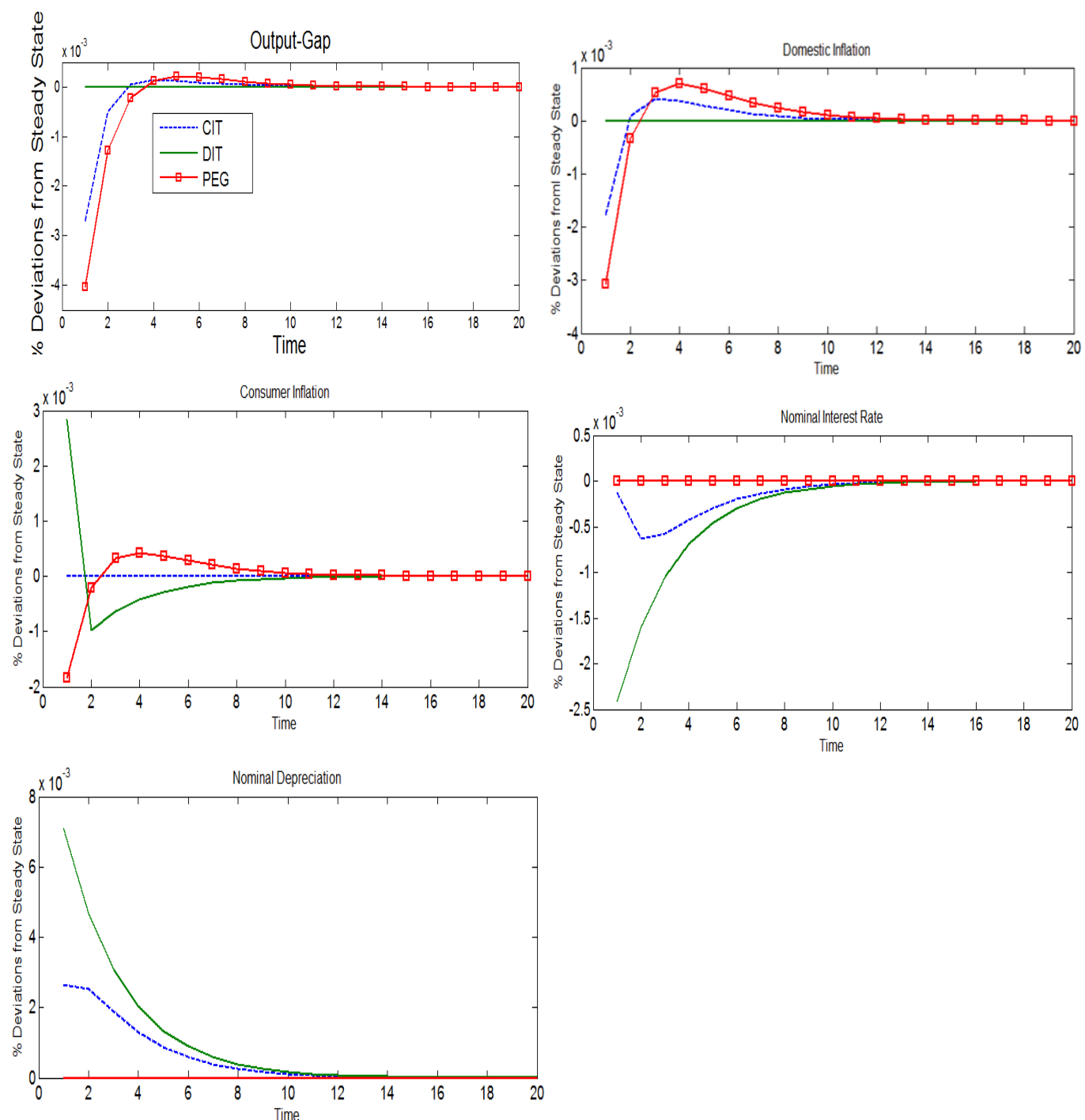


Figure 4 Impulse Responses to a Cost Push Shock: Targeting Rules.

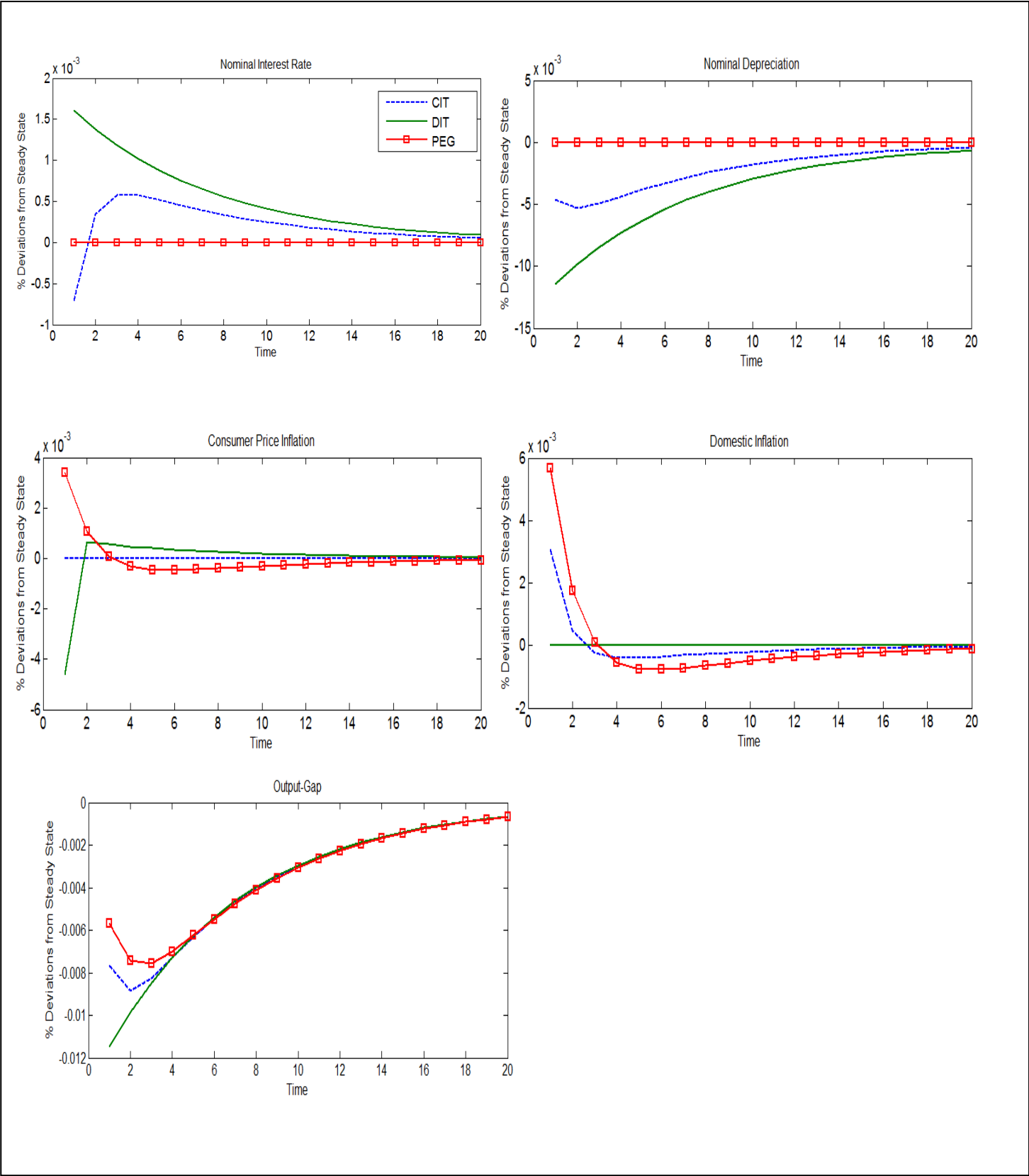
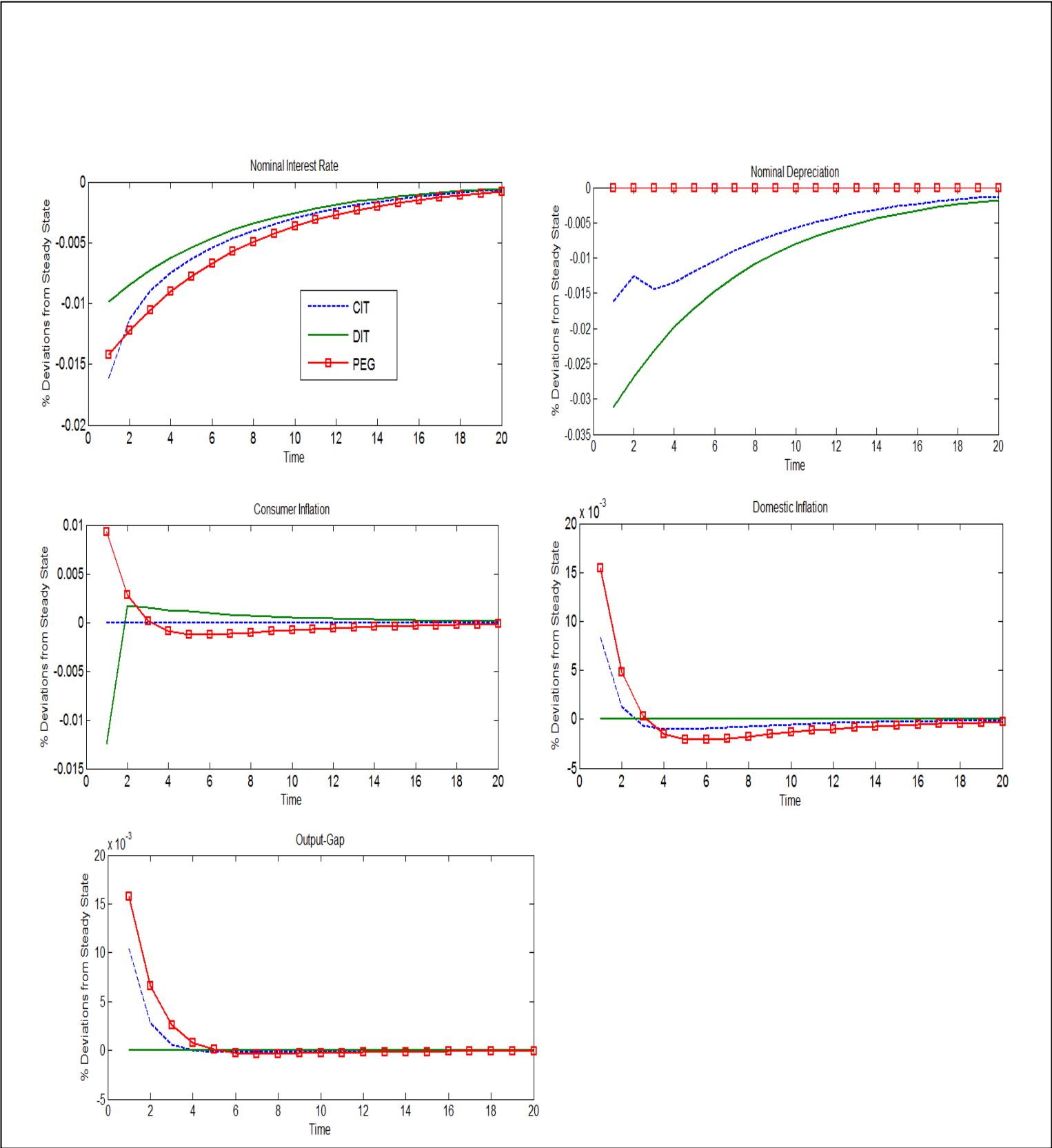
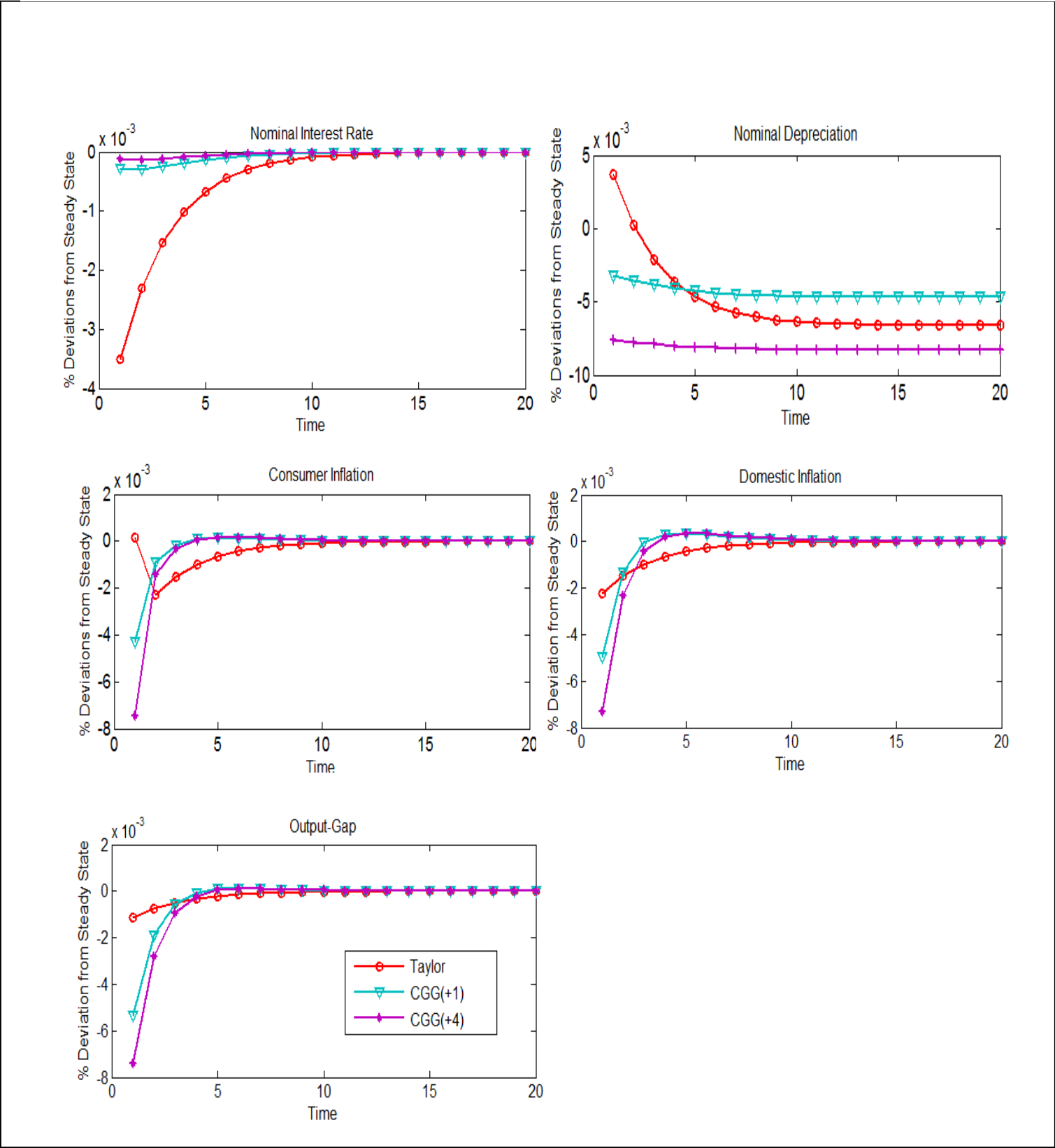


Figure 5 Impulse Responses to a Foreign Output Shock: Targeting Rules.

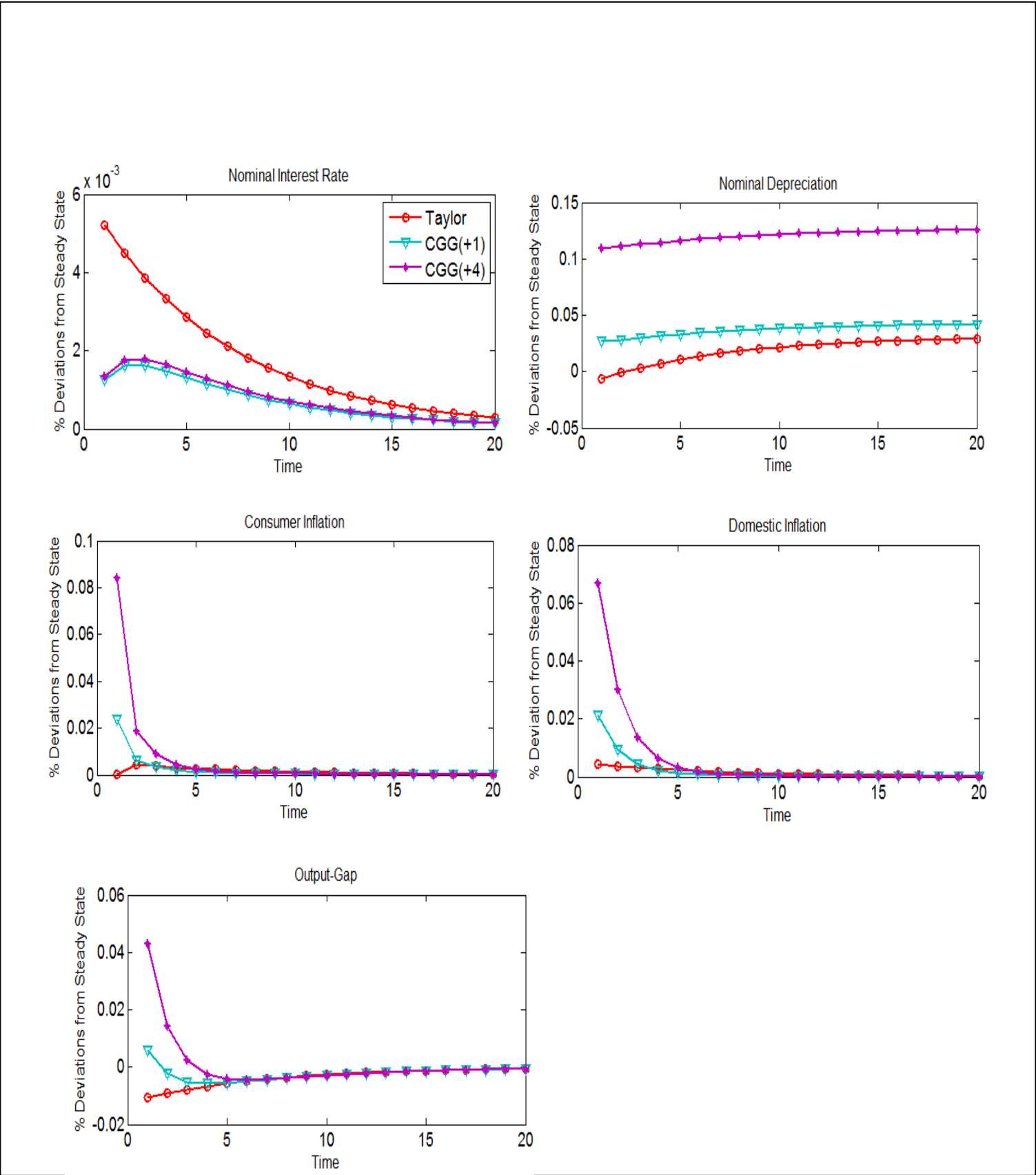




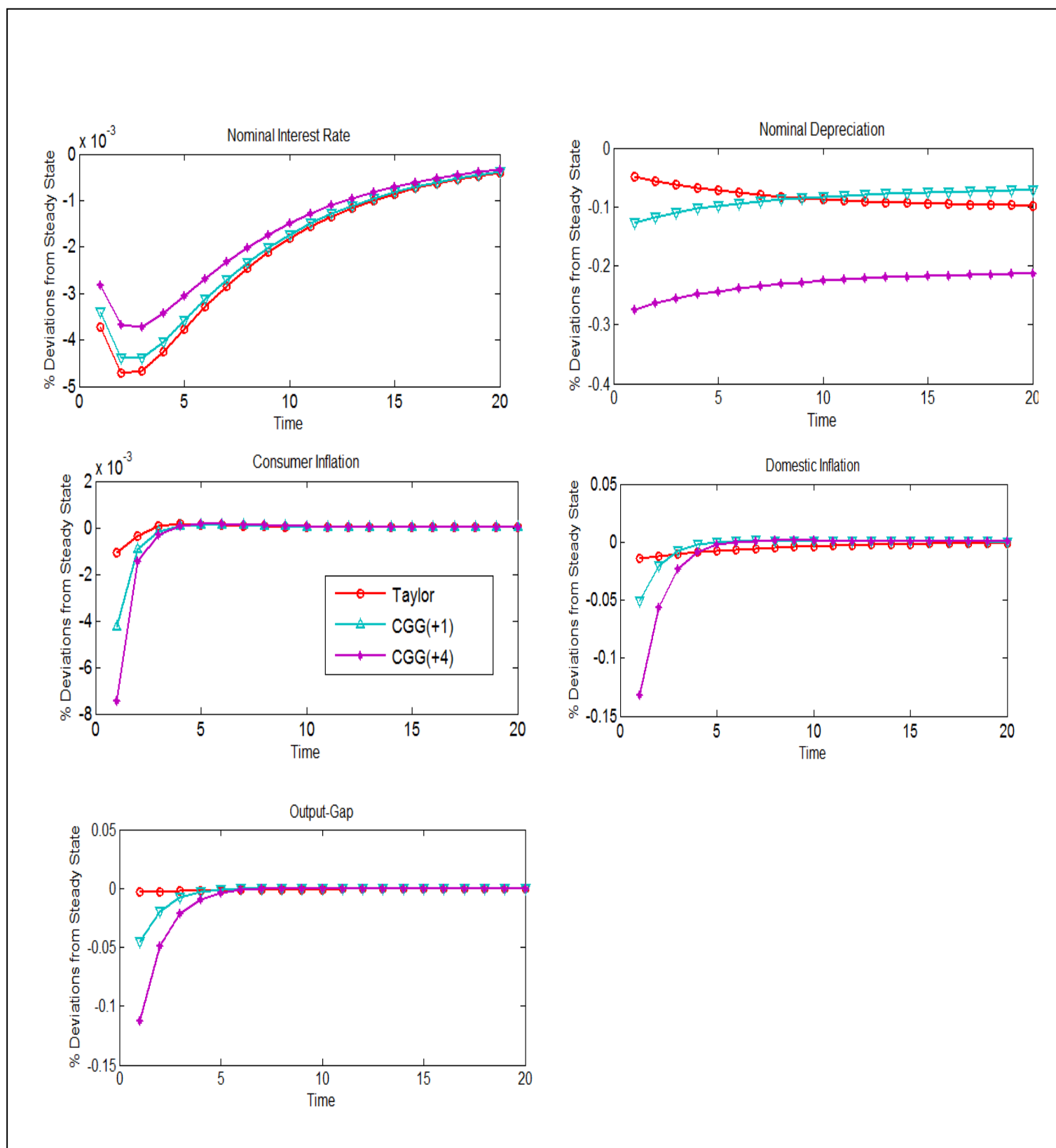
**Figure 6** Impulse Responses to a Technology Shock: Instrument Rules



**Figure 7    Impulse Responses to a Cost Push Shock: Instrument Rules.**



**Figure 8 Impulse Responses to a Foreign Output Shock: Instrument Rules.**



**Table 2 Parameter Values used in calibrating a Small Open Economy Model<sup>30</sup>.**

Parameter	Value	Description
$\beta$	0.99	The discount factor
$\sigma$	1	Coefficient of risk aversion
$\varphi$	3	Elasticity of labour supply
$\nu$	1	Substitution between foreign and domestic goods
$\alpha$	0.4	Trade openness measure
$\omega$	0.75	Price stickiness measure
$\varepsilon$	6	Elasticity of substitution between differentiated goods within an economy
$\gamma$	1	Elasticity of substitution between imported goods
$\phi_{\pi}$	1.5	Sensitivity of the central bank with respect to inflation(value as in Taylor, 1993)
$\phi_y$	5/4	Sensitivity of the central bank with respect to the output gap (value as in Taylor, 1993)
$\rho_{yx}$	0.86	Persistence of the foreign shock
$\rho_a$	0.9	Persistence of the technology shock
$\rho_u$	0.86	Persistence of the cost push shock
Parameters for the Forward Looking rules		
$\phi_i$	0.91	Sensitivity of the central bank with respect to interest rate (value as in Clarida, Galí and Gertler, 1998)
$\phi_y$	0.25	Sensitivity of the central bank with respect to the output gap (value as in Clarida, Galí and Gertler, 1998)
$\phi_{\pi}$	1.31	Sensitivity of the central bank with respect to the inflation rate (value as in Clarida, Galí and Gertler, 1998)

<sup>30</sup> Most of the parameter values are derived from Gali (2008), Gali and Monacelli (2002 ) unless if stated otherwise.

**Table 3 Volatility due to a Technology Shock.**

	<b>DIT</b>	<b>CIT</b>	<b>PEG</b>	<b>Taylor</b>	<b>CGG(+1)</b>	<b>CGG(+4)</b>
Output gap	<b>0.00</b>	0.28	0.42	0.15	0.57	0.80
Domestic inflation	<b>0.00</b>	0.19	0.33	0.30	0.52	0.77
Consumer Inflation	0.31	<b>0.00</b>	0.20	0.31	0.44	0.76
Nominal Interest rate	0.32	0.10	-	0.47	0.05	<b>0.02</b>
Nominal Depreciation	0.57	0.43	<b>0.00</b>	0.48	0.30	0.29
Output	0.95	0.75	0.62	0.79	0.50	<b>0.39</b>

**Table 4 Volatility due to a Cost Push Shock.**

	<b>DIT</b>	<b>CIT</b>	<b>PEG</b>	<b>Taylor</b>	<b>CGG(+1)</b>	<b>CGG(+4)</b>
Output gap	2.25	2.03	1.87	2.06	<b>1.54</b>	4.65
Domestic inflation	<b>0.00</b>	<b>0.32</b>	0.62	0.85	2.39	7.48
Consumer inflation	0.48	<b>0.00</b>	0.37	0.85	2.48	8.66
Nominal Interest rate	0.31	<b>0.15</b>	-	1.02	0.40	0.44
Nominal Depreciation	1.35	1.22	<b>0.00</b>	1.24	0.92	2.79
Output	2.25	2.03	1.87	2.06	<b>1.54</b>	4.65

**Table 5 Volatility due to a Foreign Output Shock.**

	<b>DIT</b>	<b>CIT</b>	<b>PEG</b>	<b>Taylor</b>	<b>CGG(+1)</b>	<b>CGG(+4)</b>
Output gap	0.00	1.08	1.73	0.60	5.03	16.13
Domestic inflation	0.00	0.88	1.70	2.76	5.55	14.56
Consumer Inflation	1.29	0.00	1.02	3.42	8.24	19.20
Nominal Interest rate	1.93	2.60	2.78	4.21	1.08	0.92
Nominal Depreciation	3.67	3.32	0.00	4.03	6.20	10.47
Output	4.59	4.03	3.63	5.19	8.91	12.48

## Appendix (E) Derivation of (3.1.6–3.1.7).

The household minimise expenditure on home good

$$\int_0^1 P_{H,t}(j) C_{H,t}(j) dj \quad (3.1.1)$$

$$\text{subject to the constraint } C_{H,t} \equiv \left( \int_0^1 C_{H,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} \quad (3.1.3)$$

To solve the constrained maximization problem, we write the Lagrangian.

$$L = \int_0^1 P_{H,t}(j) C_{H,t}(j) dj - \lambda_t \left[ \left( \int_0^1 C_{H,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} - C_{H,t} \right] \quad (E:1)$$

F.O.C

$$\frac{\partial L}{\partial C_{H,t}(j)} = P_{H,t}(j) - \lambda_t \left( \frac{\varepsilon}{\varepsilon-1} \right) \left[ \left( \int_0^1 C_{H,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}-1} \right] \left( \frac{\varepsilon-1}{\varepsilon} \right) C_{H,t}(j)^{\frac{\varepsilon-1}{\varepsilon}-1} = 0 \quad (E:2)$$

$$P_{H,t}(j) = \lambda_t \left[ \left( \int_0^1 C_{H,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{1}{\varepsilon-1}} \right] C_{H,t}(j)^{-\frac{1}{\varepsilon}} \quad (E:3)$$

$$C_{H,t}(j) = \left[ \frac{P_{H,t}(j)}{\lambda_t} \right]^{-\varepsilon} C_{H,t} \quad (E:4)$$

$$C_{H,t} \equiv \left[ \int_0^1 \left( \frac{P_{H,t}(j)}{\lambda_t} \right)^{-\varepsilon} C_{H,t}^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (E:5)$$

$$C_{H,t} \equiv C_{H,t} \lambda_t^\varepsilon \left[ \left( \int_0^1 P_{H,t}(j)^{1-\varepsilon} dj \right) \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (E:6)$$

$$\lambda_t = \left[ \int_0^1 P_{H,t}(j)^{1-\varepsilon} dj \right]^{\frac{1}{1-\varepsilon}} \equiv P_{H,t} \quad (E:7)$$

$$C_{H,t}(j) = \left( \frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\varepsilon} C_{H,t} \quad (3.1.6)$$

The household minimise expenditure on foreign good

$$\int_0^1 P_{i,t}(j) C_{i,t}(j) dj \quad (3.1.)_1$$

$$\text{subject to the constraint } C_{i,t} \equiv \left( \int_0^1 C_{i,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} \quad (3.1.)_2$$

To solve the constrained maximization problem, we write the Lagrangian.

$$L = \int_0^1 P_{i,t}(j) C_{i,t}(j) dj - \lambda_t \left[ \left( \int_0^1 C_{i,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} - C_{i,t} \right] \quad (E:8)$$

F.O.C

$$\frac{\partial L}{\partial C_{i,t}(j)} = P_{i,t}(j) - \lambda_t \left( \frac{\varepsilon}{\varepsilon-1} \right) \left[ \left( \int_0^1 C_{i,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}-1} \right] \left( \frac{\varepsilon-1}{\varepsilon} \right) C_{i,t}(j)^{\frac{\varepsilon-1}{\varepsilon}-1} = 0 \quad (E:9)$$

$$P_{i,t}(j) = \lambda_t \left[ \left( \int_0^1 C_{i,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{1}{\varepsilon-1}} \right] C_{i,t}(j)^{-\frac{1}{\varepsilon}} \quad (E:10)$$

$$C_{i,t}(j) = \left[ \frac{P_{i,t}(j)}{\lambda_t} \right]^{-\varepsilon} C_{i,t} \quad (E:11)$$

$$C_{i,t} \equiv \left[ \left( \int_0^1 \left( \frac{P_{i,t}(j)}{\lambda_t} \right)^{-\varepsilon} C_{i,t} \right)^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (E:12)$$

$$\lambda_t = \left[ \int_0^1 P_{i,t}(j)^{1-\varepsilon} dj \right]^{\frac{1}{1-\varepsilon}} \equiv P_{i,t} \quad (E:13)$$

$$C_{i,t}(j) = \left( \frac{P_{i,t}(j)}{P_{i,t}} \right)^{-\varepsilon} C_{i,t} \quad (3.1.)_3$$

The household minimise total expenditure on all foreign goods

$$\int_0^1 P_{i,t} C_{i,t} di \quad (E: 14)$$

subject to the constraint that the bundle of goods we buy must yield a given aggregate

$$\text{consumption } C_{F,t} \equiv \left( \int_0^1 C_{i,t}^{\frac{\gamma-1}{\gamma}} di \right)^{\frac{\gamma}{\gamma-1}} \quad (3.13)$$

To solve the constrained maximization problem, we set the Lagrangian.

$$L = \int_0^1 P_{i,t} C_{i,t} di - \lambda_t \left[ \left( \int_0^1 C_{i,t}^{\frac{\gamma-1}{\gamma}} di \right)^{\frac{\gamma}{\gamma-1}} - C_{F,t} \right] \quad (E: 15)$$

F.O.C

$$\frac{\partial L}{\partial C_{i,t}} = P_{i,t} - \lambda_t \left( \frac{\gamma}{\gamma-1} \right) \left[ \left( \int_0^1 C_{i,t}^{\frac{\gamma-1}{\gamma}} di \right)^{\frac{\gamma}{\gamma-1}-1} \right] \left( \frac{\gamma-1}{\gamma} \right) C_{i,t}^{\frac{\gamma-1}{\gamma}-1} = 0 \quad (E: 16)$$

$$P_{i,t} = \lambda_t \left[ \left( \int_0^1 C_{i,t}^{\frac{\gamma-1}{\gamma}} di \right)^{\frac{1}{\gamma-1}} \right] C_{i,t}^{-\frac{1}{\gamma}} \quad (E: 17)$$

$$C_{i,t} = \left[ \frac{P_{i,t}}{\lambda_t} \right]^{-\gamma} C_{F,t} \quad (E: 18)$$

$$C_{F,t} \equiv \left[ \left( \int_0^1 \left( \frac{P_{i,t}}{\lambda_t} \right)^{-\gamma} C_{F,t}^{\frac{\gamma-1}{\gamma}} di \right)^{\frac{\gamma}{\gamma-1}} \right] \quad (E: 19)$$

$$C_{F,t} \equiv C_{F,t} \lambda_t^\gamma \left[ \left( \int_0^1 (P_{i,t})^{1-\gamma} di \right)^{\frac{\gamma}{1-\gamma}} \right] \quad (E: 20)$$

$$\lambda_t = \left[ \int_0^1 P_{i,t}^{1-\gamma} di \right]^{\frac{1}{1-\gamma}} \equiv P_{F,t} \quad (E: 21)$$



$$C_{i,t} = \left[ \frac{P_{i,t}}{P_{F,t}} \right]^{-\gamma} C_{F,t} \quad (3.1.7)$$

The End.

## Appendix (F) Derivation of (3.1.10–3.1.16)

The second problem faced by the consumer is to maximise the consumption expenditure given the constraint that the amount he or she buy must yield the total consumption:

$$C_t = \left[ (1-\alpha)^{\frac{1}{\nu}} C_{H,t}^{\frac{\nu-1}{\nu}} + \alpha^{\frac{1}{\nu}} C_{F,t}^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}} \quad (3.1.10)$$

Subject to the constraint

$$P_{H,t} C_{H,t} + P_{F,t} C_{F,t} = P_t C_t \quad (3.1.11)$$

Formalise with the lagrangian multiplier

$$L_{C_{H,t}, C_{F,t}, C_t} = \left[ (1-\alpha)^{\frac{1}{\nu}} C_{H,t}^{\frac{\nu-1}{\nu}} + \alpha^{\frac{1}{\nu}} C_{F,t}^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}} + \psi_t [P_{H,t} C_{H,t} + P_{F,t} C_{F,t} - P_t C_t] \quad (F:1)$$

FOC for the domestic good

$$\frac{\partial L}{\partial C_{H,t}} = \left( \frac{\nu}{\nu-1} \right) \left[ (1-\alpha)^{\frac{1}{\nu}} C_{H,t}^{\frac{\nu-1}{\nu}} + \alpha^{\frac{1}{\nu}} C_{F,t}^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}-1} \left( \frac{\nu-1}{\nu} \right) (1-\alpha)^{\frac{1}{\nu}} C_{H,t}^{\frac{\nu-1}{\nu}-1} + \psi_t P_{H,t} = 0 \quad (F:2)$$

$$P_{H,t} = \psi_t \left[ (1-\alpha)^{\frac{1}{\nu}} C_{H,t}^{\frac{\nu-1}{\nu}} + \alpha^{\frac{1}{\nu}} C_{F,t}^{\frac{\nu-1}{\nu}} \right]^{\frac{1}{\nu-1}} (1-\alpha)^{\frac{1}{\nu}} C_{H,t}^{\frac{\nu-1}{\nu}-1} \quad (F:3)$$

$$P_{H,t} = \psi_t \left[ (1-\alpha)^{\frac{1}{\nu}} C_{H,t}^{\frac{\nu-1}{\nu}} + \alpha^{\frac{1}{\nu}} C_{F,t}^{\frac{\nu-1}{\nu}} \right]^{\frac{1}{\nu}} (1-\alpha)^{\frac{1}{\nu}} C_{H,t}^{\frac{1}{\nu}} \quad (F:4)$$

FOC for the foreign good

$$\frac{\partial L}{\partial C_{F,t}} = \left( \frac{\nu}{\nu-1} \right) \left[ (1-\alpha)^{\frac{1}{\nu}} C_{H,t}^{\frac{\nu-1}{\nu}} + \alpha^{\frac{1}{\nu}} C_{F,t}^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}-1} \left( \frac{\nu-1}{\nu} \right) \alpha^{\frac{1}{\nu}} C_{F,t}^{\frac{\nu-1}{\nu}-1} + \psi_t P_{F,t} = 0 \quad (F:5)$$

$$P_{F,t} = \psi_t \left[ (1-\alpha)^{\frac{1}{\nu}} C_{H,t}^{\frac{\nu-1}{\nu}} + \alpha^{\frac{1}{\nu}} C_{F,t}^{\frac{\nu-1}{\nu}} \right]^{\frac{1}{\nu}} \alpha^{\frac{1}{\nu}} C_{F,t}^{\frac{1}{\nu}} \quad (F:6)$$

$$P_{H,t} = \psi_t C_t^{\frac{1}{\nu}} (1-\alpha)^{\frac{1}{\nu}} C_{H,t}^{\frac{1}{\nu}} \quad (F:7)$$

$$C_{H,t} = (1-\alpha) \left[ \frac{P_{H,t}}{\psi_t} \right]^{-\nu} C_t \quad (F:8)$$

$$C_{F,t} = (\alpha) \left[ \frac{P_{F,t}}{\psi_t} \right]^{-\nu} C_t \quad (F:9)$$

Substituting the solutions for  $(C_{H,t})$  and  $(C_{F,t})$  into (3.1.2).

$$C_t \equiv \left\{ 1 - \alpha^{\frac{1}{\nu}} \left[ 1 - \alpha \left[ \frac{P_{H,t}}{\psi_t} \right]^{-\nu} C_t \right]^{\frac{\nu-1}{\nu}} + (\alpha)^{\frac{1}{\nu}} \left[ (\alpha) \left[ \frac{P_{F,t}}{\psi_t} \right]^{-\nu} C_t \right]^{\frac{\nu-1}{\nu}} \right\}^{\frac{\nu}{\nu-1}} \quad (F:10)$$

$$C_t \equiv \left\{ (1-\alpha)^{\frac{1}{\nu}} (1-\alpha)^{\frac{1}{\nu}} \left[ \frac{P_{H,t}}{\psi_t} \right]^{-\nu \frac{\nu-1}{\nu}} C_t^{\frac{\nu-1}{\nu}} + (\alpha)^{\frac{1}{\nu}} (\alpha)^{\frac{\nu-1}{\nu}} \left[ \frac{P_{F,t}}{\psi_t} \right]^{-\nu \frac{\nu-1}{\nu}} C_t^{\frac{\nu-1}{\nu}} \right\}^{\frac{\nu}{\nu-1}} \quad (F:11)$$

$$1 \equiv \left\{ 1 - \alpha \left[ \frac{P_{H,t}}{\psi_t} \right]^{1-\nu} + (\alpha) \left[ \frac{P_{F,t}}{\psi_t} \right]^{1-\nu} \right\}^{\frac{\nu}{\nu-1}} \quad (F:13)$$

$$\psi_t \equiv \left\{ (1-\alpha) P_{H,t}^{1-\nu} + (\alpha) P_{F,t}^{1-\nu} \right\}^{\frac{1}{\nu-1}} \equiv P_t \quad (F:13)$$

$$P_t \equiv \left\{ (1-\alpha) P_{H,t}^{1-\nu} + (\alpha) P_{F,t}^{1-\nu} \right\}^{\frac{1}{\nu-1}} \quad (3.1.11)$$

$$C_{H,t} = (1-\alpha) \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} C_t \quad (3.1.10)$$

$$C_{F,t} = (\alpha) \left[ \frac{P_{F,t}}{P_t} \right]^{-\nu} C_t \quad (3.1.10)$$

The End.

## Utility Maximization

The household maximizes utility:  $E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\eta}}{1+\eta} \right\}$  subject to the constraint:

$$P_t C_t + E_t \{Q_{t,t+1} D_{t+1}\} \leq D_t + W_t N_t + T_t$$

To solve the maximization problem, we first set out the Lagrangian Function:

$$L = \sum_{t=0}^{\infty} \beta^t \left\{ \left( \frac{C_t}{1-\sigma} \right)^{1-\sigma} - \left( \frac{N_t^{1+\eta}}{1+\eta} \right) \right\} + \lambda_t \left\{ D_t + W_t N_t + T_t - (P_t C_t + E_t \{Q_{t,t+1} D_{t+1}\}) \right\} \quad (F: 1 \text{ a})$$

$$\frac{\partial L}{\partial C_t} : C_t^{-\sigma} - \lambda_t P_t = 0 \quad (F: 1 \text{ b})$$

$$C_t^{-\sigma} = \lambda_t P_t \quad (F: 1 \text{ c})$$

$$C_{t+1}^{-\sigma} = \lambda_{t+1} P_{t+1} \quad (F: 1 \text{ d})$$

$$\frac{\lambda_{t+1}}{\lambda_t} = \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \quad (F: 1 \text{ e})$$

$$\frac{\partial L}{\partial N_t} : -N_t^{\eta} + \lambda_t W_t = 0 \quad (F: 1 \text{ f})$$

$$N_t^{\eta} = \lambda_t W_t \quad (F: 2 \text{ a})$$

$$\frac{N_t^{\eta}}{C_t^{-\sigma}} = \frac{\lambda_t W_t}{\lambda_t P_t} = \frac{W_t}{P_t} \quad (F: 2 \text{ b})$$

$$C_t^{\sigma} N_t^{\eta} = \frac{W_t}{P_t} \quad (3.1.1)$$

$$\frac{\partial L}{\partial D_{t+1}} : -\lambda_t E_t Q_{t,t+1} + \beta(\lambda_{t+1}) = 0 \quad (F: 2 \text{ c})$$

$$\lambda_t E_t Q_{t,t+1} = \beta(\lambda_{t+1}) \quad (F: 2 \text{ d})$$

$$E_t Q_{t,t+1} = \beta \frac{\lambda_{t+1}}{\lambda_t} \quad (F: 2 \text{ e})$$

Substitute for  $\frac{\lambda_{t+1}}{\lambda_t}$

$$Q_{t,t+1} = \beta E_t \left\{ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right\} \quad (F : 2 \S)$$

Divide both sides by  $Q_{t,t+1}$

$$1 = \beta R_t E_t \left\{ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right\} \quad (3.1.1)$$

$$\text{where } R_t = \frac{1}{Q_{t,t+1}} \quad (F : 2 \S)$$

or

$$1 = \beta E_t \left\{ Q_{t+1}^{-1} \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right\} \quad (F : 2 \S)$$

Taking log the Euler equation (F : 27).

$$Q_{t+1} = \beta \left\{ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right\}$$

Taking logs

$$\ln Q_{t+1} = \ln \beta - \sigma \ln C_{t+1} + \sigma \ln C_t + \ln P_t - \ln P_{t+1}$$

Solving for  $C_t$

$$-\sigma \ln C_t = -\sigma \ln C_{t+1} - \ln Q_{t+1} + \ln P_t - \ln P_{t+1} + \ln \beta$$

$$c_t = E_t \{ c_{t+1} \} - \frac{1}{\sigma} (i_t - E_t \{ \pi_{t+1} \} - \rho) \quad (3.1.16)$$

Where  $i_t \equiv -\ln Q_{t+1}$ ;  $\pi_{t+1} = p_t - p_{t+1}$  and  $\rho \equiv -\ln \beta$

The End.

**Appendix (G): Derivation of (3.1.19–3.1.27)**

$$S_t \equiv \frac{P_{F,t}}{P_{H,t}} \quad (G:1)$$

$$= \left( \int_0^1 S_{i,t}^{1-\gamma} di \right)^{\frac{1}{1-\gamma}} \quad (G:2)$$

$$1 + \ln s_t = 1 + \ln \left( \int_0^1 S_{i,t}^{1-\gamma} di \right)^{\frac{1}{1-\gamma}} \quad (G:3)$$

$$1 + \ln s_t = 1 + \ln \left( \int_0^1 (1-\gamma) S_{i,t} di \right)^{\frac{1}{1-\gamma}} \quad (G:4)$$

$$s_t = \int_0^1 s_{i,t} di \quad (3.1.1)$$

Log- linearizing the CPI equation (3.1.11) around a steady state where  $P_{H,t} = P_F = P$ :

$$\begin{aligned} P_t &\approx \left[ (1-\alpha)P^{1-\nu} + \alpha P^{1-\nu} \right]^{\frac{1}{1-\nu}} + \frac{1}{1-\nu} \left[ (1-\alpha)P^{1-\nu} + \alpha P^{1-\nu} \right]^{\frac{1}{1-\nu}-1} \left[ \begin{aligned} &(1-\alpha)(1-\nu)P^{-\nu}(P_{H,t}-P) \\ &+ \alpha(1-\nu)P^{-\nu}(P_{F,t}-P) \end{aligned} \right] \\ &= P + \left[ (1-\alpha)(P_{H,t}-P) + \alpha(P_{F,t}-P) \right] \end{aligned} \quad (G:5)$$

$$p_t \approx P_{H,t} - \alpha P_{H,t} + \alpha P_{F,t} \quad (G:6)$$

$$p_t \approx P_{H,t} + \alpha(P_{F,t} - P_{H,t}) \quad (G:7)$$

$$p_t \approx P_{H,t} + \alpha s_t \quad (3.1.2)$$

$$P_{F,t} = \int_0^1 (e_{i,t} P_{i,t}^i) di \quad (G:8)$$

$$1 + \ln P_{F,t} = 1 + \ln \int_0^1 (e_{i,t} di + P_{i,t}^i di) \quad (G:9)$$

$$P_{F,t} = e_t + p_t^* \quad (G:10)$$

$$e_t + p_t^* - p_{F,t} = s_t - p_{F,t} + p_{H,t} \quad (G:11)$$

$$\varepsilon_t + p_t^* = s_t + p_{H,t} \quad (G:12)$$

$$\varepsilon_t + p_t^* - p_{H,t} = s_t \quad (G:13)$$

$$s_t = e_t + p_t^* - p_{H,t} \quad (3.1.23)$$

Defining the bilateral exchange rate between the home country and country  $i$  as the ratio of the two countries' CPIs, but expressed in terms of the domestic currency as:

$$Q_{i,t} \equiv \frac{e_{i,t} p_t^i}{p_t} \quad (G: 14)$$

Taking logs

$$q_{it} = e_{it} + p_t^i - p_t \quad (G: 15)$$

The log effective real exchange rate is:

$$q_t \equiv \int_0^1 q_{i,t} di \quad (G: 16)$$

Insert

$$q_t = \int_0^1 (e_{i,t} + p_t^i - p_t) di \quad (G: 17)$$

$$1 + \ln q_t = 1 + \ln \int_0^1 e_{i,t} di + \int_0^1 p_t^i di - \int_0^1 p_t di \quad (G: 18)$$

$$= s_t + p_{H,t} - p \quad (G: 19)$$

$$= s_t + p_{H,t} - p_{H,t} + \alpha s_t \quad (G: 20)$$

$$q_t = (1 - \alpha) s_t \quad (3.1.27)$$

The End



## Appendix (H) Derivation of (3.1.31–3.1.38)

From (3.1.29) the Euler equation of the foreign economy is:

$$1 = \beta R_t E_t \left\{ \left( \frac{C_{t+1}^i}{C_t^i} \right)^{-\sigma} \left( \frac{e_t^i P_t^i}{e_{t+1}^i P_{t+1}^i} \right) \right\} \quad (3.1.2)$$

The Euler for the domestic economy is given by (3.1.14).

$$1 = \beta R_t E_t \left\{ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \left( \frac{P_t}{P_{t+1}} \right) \right\} \quad (3.1.3)$$

Divide the two Euler Equations

$$1 = \frac{\beta R_t E_t \left\{ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \left( \frac{P_t}{P_{t+1}} \right) \right\}}{\beta R_t E_t \left\{ \left( \frac{C_{t+1}^i}{C_t^i} \right)^{-\sigma} \left( \frac{P_t^i e_t^i}{P_{t+1}^i e_{t+1}^i} \right) \right\}} \quad (H:1)$$

Rewrite the above as:

$$E_t \left\{ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \left( \frac{C_{t+1}^i}{C_t^i} \right)^{\sigma} \frac{P_{t+1}^i e_{t+1}^i}{P_t^i e_t^i} \right\} \quad (H:2)$$

$$(C_t)^{-\sigma} = E_t \left\{ \left( \frac{C_{t+1}^i}{C_t} \right)^\sigma (C_t^i)^{-\sigma} \frac{\frac{P_{t+1}^i e_{t+1}^i}{P_t}}{\frac{P_{t+1}}{P_t}} \right\} \quad (H:3)$$

$$C_t^{-\sigma} = E_t \left\{ \left( \frac{C_{t+1}^i}{C_{t+1t}} \right)^\sigma (C_t^i)^{-\sigma} \frac{Q_{i,t+1}}{Q_{i,t}} \right\} \quad (H:4)$$

$$C_t = E_t \left\{ \left( \frac{C_{t+1}}{C_{t+1}^i Q_{i,t+1}^{\frac{1}{\sigma}}} \right) (C_t^i) Q_{i,t}^{\frac{1}{\sigma}} \right\} \quad (H:5)$$

$$C_t = \mathcal{G}(C_t^i) Q_{i,t}^{\frac{1}{\sigma}} \quad (3.1.3)$$

$$\mathcal{G} = E_t \left( \frac{C_{t+1}}{C_{t+1}^i Q_{i,t+1}^{\frac{1}{\sigma}}} \right) \quad (H:6)$$

Take log of (3.1.31).

$$\log C_t = \log \mathcal{G} + \log C_t^i + \log Q_{i,t}^{\frac{1}{\sigma}} \quad (H:7)$$

$$c_t = c_t^i + \frac{1}{\sigma} q_{i,t}, \quad (H:8)$$

$$c_t = \int_0^1 \left( c_t^i + \frac{1}{\sigma} \right) di$$

$$c_t = c_t^* + \left( \frac{1}{\sigma} \right) q_t \quad (H:9)$$

$$c_t = c_t^* + \left( \frac{1-\alpha}{\sigma} \right) s_t \quad (3.1.3)$$

The complete international financial markets assumption implies that the equilibrium price of a riskless bond denominated in the currency of country  $i$  is given by  $e_{i,t} Q_t^i = E_t \{ Q_{i,t+1} e_{i,t+1} \}$ . The equation for the domestic bond price is stated as:  $Q_t = E_t \{ Q_{i,t+1} \}$ ,

where  $Q_t^i$  denotes the price of the bond expressed in the currency of country  $i$ . Combining the two expressions yields the uncovered interest parity as follows:

$$E_t \{ Q_{t,t+1} e_{i,t+1} \} - e_{i,t} Q_t^i = E_t \{ Q_{t,t+1} \}^{-1} + Q_t \quad (H:10)$$

$$E_t \{ Q_{t,t+1} [ (Q_t - Q_t^i) e_{i,t+1} - e_{i,t} ] \} = 0 \quad (3.1.3)$$

$$E_t [ 1 + \ln Q_{t,t+1} + 1 + \ln Q_t - 1 + \ln Q_t^i + 1 + \ln e_{i,t+1} - 1 + \ln e_{i,t} ] = 1 + \ln 0 \quad (H:11)$$

$$\text{where } 1 + i_t = 1 + Q_t, 1 + i_t^i = 1 + Q_t^i : \quad (H:12)$$

$$i_t - i_t^* + E_t \{ \Delta e_{t+1} \} \quad (3.1.3)$$

$$\text{Where } 1 + i_t = Q_t, 1 + i_t^* = Q_t^i :$$

$$s_t = e_t + P_t^* - P_{H,t} \quad (H:13)$$

$$E_t s_{t+1} - s_t = E_t e_{t+1} - e_t + E_t P_{t+1}^* - P_t^* - E_t P_{H,t+1} - P_{H,t} \quad (3.1.3)$$

$$s_t = -E_t \Delta e_{t+1} - E_t \pi_{t+1}^* + E_t \pi_{H,t+1} + E_t s_{t+1} \quad (H:14)$$

$$s_t = (i_t^* - E_t \pi_{t+1}^*) - (i_t - E_t \pi_{H,t+1}) + E_t s_{t+1} \quad (3.1.3)$$

In the steady the terms of trade are pinned down, thus it follows that  $\lim_{T \rightarrow \infty} E_t s_T = 0$ .

We can thus solve forward the above equation.

$$s_t = (i_t^* - E_t \pi_{t+1}^*) - (i_t - E_t \pi_{H,t+1}) + E_t (i_{t+1}^* - \pi_{t+2}^*) - \quad (H:15)$$

$$E_t (i_{t+1} - \pi_{t+2}) + E_t (i_{t+2}^* - \pi_{t+3}^*) - E_t (i_{t+2} - \pi_{t+3})$$

$$s_t = E_t \left\{ \sum_{k=0}^{\infty} [ (i_{t+k}^* - E_t \pi_{t+k}^*) - (i_{t+k} - E_t \pi_{t+k}) ] \right\} \quad (3.1.38)$$

The End.

## Appendix (I) Derivation of (3.1.41-3.1.47)

The domestic price level is given by:

$$P_{H,t} = \left[ (1 - \omega_H) \bar{P}_{H,t}^{1-\nu} + \omega_H P_{H,t}^{1-\nu} \right]^{\frac{1}{1-\nu}} \quad (3.1.41)$$

where  $\bar{P}_{H,t}$  is the price of optimising firms, while  $P_{H,t-1}$  is the price level of no optimising firms. Log-linearizing (3.1.41) gives:

$$\begin{aligned} P_{H,t} &= \left[ (1 - \omega_H) \bar{P}_{H,t}^{1-\nu} + \omega_H P_{H,t-1}^{1-\nu} \right]^{\frac{1}{1-\nu}} \\ P_H (1 + p_{H,t}) &= \left[ P_H^{1-\nu} (1 - \omega_H) + (1 - \omega_H)^* (1 - \nu) (\bar{P}_{H,t}) + \omega_H + \omega_H^* (1 - \nu) (P_{H,t-1}) \right]^{\frac{1}{1-\nu}} \\ p_{H,t} &= (1 - \omega_H) (\bar{p}_{H,t} - p_{H,t-1}) \end{aligned} \quad (3.1.42)$$

The firm ( $j$ ) wants to maximize the following function

$$\frac{\max}{\bar{p}_{H,t}(j)} \sum_{k=0}^{\infty} \omega_H^k E_t (Q_{t,t+k}) \left[ Y_{t+k}^d(j) (\bar{P}_{H,t}(j) - MC_{t+k}^n(j)) \right] \quad (3.1.43)$$

Subject to a sequence of demand constraints

$$Y_{t+k}^d(j) = \left( \frac{\bar{P}_{H,t}}{P_{H,t+k}} \right)^{-\varepsilon} y_{t+k} \quad (3.1.44)$$

$$k = 0, 1, 2$$

If all firms undertake the same maximization process, we can drop the ( $j$ ) and write (3.1.43) as:

$$\frac{\max}{\bar{P}_{H,t}} \sum_{k=0}^{\infty} \omega_H^k E_t(Q_{t,t+k}) \left[ \left( \bar{P}_{H,t} Y_{t+k}^d - MC_{t+k}^n Y_{t+k}^d \right) \right] \quad (I:1)$$

Substituting for the sequence of demand constraints.

$$\frac{\max}{\bar{P}_{H,t}} \sum_{k=0}^{\infty} \omega_H^k E_t(Q_{t,t+k}) \left[ \left( \left( \frac{\bar{P}_{H,t}}{P_{H,t+k}} \right)^{1-\varepsilon} Y_{t+k} P_{H,t+k} - MC_{t+k}^n \left( \frac{\bar{P}_{H,t}}{P_{H,t+k}} \right)^{-\varepsilon} Y_{t+k} \right) \right] \quad (I:2)$$

The first order condition with respect to the optimality price  $\bar{P}_{H,t}$  is:

$$\sum_{k=0}^{\infty} \omega_H^k E_t \left\{ Q_{t,t+k} \left[ \begin{aligned} & \left( (1-\varepsilon) \left( \frac{\bar{P}_{H,t}}{P_{H,t+k}} \right)^{-\varepsilon} \frac{1}{P_{H,t+k}} Y_{t+k} P_{H,t+k} - \right. \\ & \left. (-\varepsilon) MC_{t+k}^n \left( \frac{\bar{P}_{H,t}}{P_{H,t+k}} \right)^{-\varepsilon-1} \frac{1}{P_{H,t+k}} Y_{t+k} \right) \end{aligned} \right] \right\} \quad (I:3)$$

$$\sum_{k=0}^{\infty} \omega_H^k E_t(Q_{t,t+k}) \left[ \left( (1-\varepsilon) \left( \frac{\bar{P}_{H,t}}{P_{H,t+k}} \right)^{-\varepsilon} Y_{t+k} + \varepsilon MC_{t+k}^n \left( \frac{\bar{P}_{H,t}}{P_{H,t+k}} \right)^{-\varepsilon} Y_{t+k} \frac{1}{\bar{P}_{H,t}} \right) \right] \quad (I:4)$$

$$\sum_{k=0}^{\infty} \omega_H^k E_t(Q_{t,t+k} Y_{t+k}^d) \left[ \left( (1-\varepsilon) + \varepsilon MC_{t+k}^n Y_{t+k}^d \frac{1}{\bar{P}_{H,t}} \right) \right] = 0 \quad (I:5)$$

$$\left( \frac{1-\varepsilon}{\bar{P}_{H,t}} \right) \sum_{k=0}^{\infty} \omega_H^k E_t(Q_{t,t+k} Y_{t+k}^d) \left[ \left( \bar{P}_{H,t} - \left( \frac{\varepsilon}{\varepsilon-1} \right) MC_{t+k}^n Y_{t+k}^d \right) \right] = 0 \quad (I:6)$$

$$\sum_{k=0}^{\infty} \omega_H^k E_t(Q_{t,t+k} Y_{t+k}^d) \left[ \left( \bar{P}_{H,t} - \left( \frac{\varepsilon}{\varepsilon-1} \right) MC_{t+k}^n Y_{t+k}^d \right) \right] = 0 \quad (3.1.4)$$

We can re-write the above equation as

$$\sum_{k=0}^{\infty} \omega_H^k E_t(Q_{t,t+k} Y_{t+k}^d) \left[ \left( \bar{P}_{H,t} - m \psi_{t+k} \right) \right] = 0 \quad (I:7)$$

where,  $m = \frac{\varepsilon}{\varepsilon-1}$  stands for the mark up due to monopolistic competition.

$\psi_{t+k} = MC_{t+k}^n Y_{t+k}^d$  is the nominal marginal cost. Log-linearizing the optimal price setting (I.12) about the zero inflation steady state. First we re-write it in terms of variables with well-defined steady state and then divide by  $P_{H,t-1}$ .

$$\sum_{k=0}^{\infty} \omega_H^k E_t \left\{ Q_{t,t+k} Y_{t+k}^d \left( \frac{\bar{P}_{H,t}}{P_{H,t-1}} - m \cdot \frac{\psi_{t+k}}{P_{H,t+k}} \frac{P_{H,t+k}}{P_{H,t-1}} \right) \right\} = 0 \quad (I:8)$$

This can be presented as:

$$\sum_{k=0}^{\infty} \omega_H^k E_t \left\{ Q_{t,t+k} Y_{t+k}^d \left( \frac{\bar{P}_{H,t}}{P_{H,t-1}} - m \cdot MC_{t+k|t} \Pi_{t-1,t+k} \right) \right\} = 0 \quad (I:9)$$

where  $MC_{t+k|t} \equiv \psi_{t+k|t} / P_{H,t+k}$  is the real marginal cost in period  $t+k$  for a firm which last reset its price in period  $t$ .  $\Pi_{t-1,t+k} \equiv P_{H,t+k} / P_{H,t-1}$  is the gross inflation between  $t-1$  and  $t+k$ . It is assumed that in the zero inflation steady state  $\bar{P}_{H,t} / P_{H,t-1} = 1$ . This implies further that  $\bar{P}_{H,t} = P_{H,t+k}$ . Moreover,  $Y_{t+k}^d = Y$  (constant) and  $MC_{t+k} = MC$ . Furthermore,

$$Q_{t,t+k} = \left( \frac{C_{t+k}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+k}} = \beta^k \quad (I:10)$$

Thus we re-write (2.2.23) as, ignoring  $Y_{t+k|t}$

$$\sum_{k=0}^{\infty} (\beta \omega_H)^k E_t \left\{ \frac{\bar{P}_{H,t}}{P_{H,t-1}} - m \cdot MC_{t+k|t} \frac{P_{H,t+k}}{P_{H,t-1}} \right\} = 0 \quad (I:11)$$

We log-linearize the equation above around the zero inflation steady state.

Where the first order Taylor expansion on  $\exp(\hat{x}_t)$  around zero is given by:

$$\exp(\hat{x}_t) = \exp(0) + \frac{\partial \exp(\hat{x}_t)}{\partial \hat{x}_t} \Big|_{\hat{x}_t=0} (\hat{x}_t - 0) \quad (I:12)$$

$$\exp(\hat{x}_t) = \exp(0) + \exp(0) (\hat{x}_t - 0) \quad (I:13)$$

$$\exp(\hat{x}_t) = 1 + \hat{x}_t$$

Applying the Taylor formula proceeds as follows:

$$\sum_{k=0}^{\infty} (\beta \omega)^k E_t \left\{ \left( \exp(\bar{P}_{H,t} - P_{H,t-1}) \right) - \exp(\mu + MC_{t+k|t} + P_{H,t+k} - P_{H,t-1}) \right\} = 0; \quad (I:14)$$

where  $\mu \equiv \log(m)$ .

$$\sum_{k=0}^{\infty} (\beta \omega)^k E_t \left\{ \left( 1 + (\bar{p}_{H,t} - p_{H,t-1}) \right) + \left( 1 + mc_{t+k|t} + p_{H,t+k} - p_{H,t-1} \right) \right\} = 0 \quad (I:15)$$

where  $mc_{t+k|t} \equiv mc_{t+k|t} - mc = mc_{t+k|t} + \log M = mc_{t+k|t} + \mu.$  (I: 16)

Re- arranging the terms

$$\sum_{k=0}^{\infty} (\beta \omega_H)^k E_t (\bar{p}_{H,t} - p_{H,t-1}) = \sum_{k=0}^{\infty} (\beta \omega_H)^k E_t (mc_{t+k} + P_{H,t+k} - P_{H,t-1})$$
 (I: 17)

$$\bar{p}_{H,t} - p_{H,t-1} = 1 - \beta \omega_H E_t \sum_{k=0}^{\infty} (\beta \omega_H)^k mc_{t+k} + P_{H,t+k} - P_{H,t-1}$$
 (I: 18)

To gain some intuition about the factors which determine the price setting of the firm we can present (I.18) as:

$$\bar{p}_{H,t} = (1 - \beta \omega_H) E_t \sum_{k=0}^{\infty} (\beta \omega_H)^k mc_{t+k} + P_{H,t+k}$$
 (3.1.4)

Alternatively (I.18) can be written as:

$$\bar{p}_{H,t} = (\beta \omega_H)^k E_t (\bar{p}_{H,t+1}) + (1 - \beta \omega_H) (mc_t + p_{H,t})$$
 (I: 19)

$$\bar{p}_{H,t} - p_{H,t-1} = (\beta \omega_H)^k E_t (\bar{p}_{H,t+1} - p_{H,t}) + (1 - \beta \omega_H) mc_t + \pi_{H,t}$$
 (I: 20)

Combine the equation above with the log-linearised version of the domestic price level.

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \frac{(1 - \omega_H)(1 - \beta \omega_H)}{\omega_H} mc_t$$
 (I: 21)

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \lambda_H mc_t,$$
 (3.1.4)

where  $\lambda_H = \frac{(1 - \omega_H)(1 - \beta \omega_H)}{\omega_H}$

The End.

## Appendix (J) Derivation of (3.1.49–3.1.79)

In equilibrium the domestic production of good  $Y_t(j)$  must be equal to domestic consumption  $C_{H,t}(j)$  and foreign consumption  $C_{H,t}^i(j)$ .

$$Y_t(j) = C_{H,t}(j) + \int_0^1 C_{H,t}^i(j) di \quad (3.1.4)$$

To derive the equilibrium output we undertake the following: Insert (3.1.10) into (3.1.6)

$$\text{i.e. } C_{H,t} = (1 - \alpha) \left( \frac{P_{H,t}}{P_t} \right)^{-\nu} C_t$$

$$C_{H,t}(j) = \left( \frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\varepsilon} (1 - \alpha) \left( \frac{P_{H,t}}{P_t} \right)^{-\nu} C_t \quad (J.1)$$

$$= (1 - \alpha) \left( \frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\varepsilon} \left( \frac{P_{H,t}}{P_t} \right)^{-\nu} C_t \quad (J.2)$$

The demand for good  $(j)$  in country  $(i)$  is obtained by nesting up across different demand layers in country  $(i)$  is a function of country  $(i)$ . First we take into account the fact that the consumption of domestically produced good  $(j)$  in country  $(i)$  is a function of country  $i$ 's consumption of goods produced in the domestic economy, given as in (3.1.6):

$$C_{H,t}^i(j) = \left( \frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\varepsilon} C_{H,t}^i \quad (J.3)$$

Country  $i$ 's consumption of goods produced in the home economy is a function of country  $i$ 's consumption of foreign goods, given as in (3.1.7) multiplied by the exchange rate:

$$C_{H,t}^i = \left( \frac{P_{H,t}}{e_{i,t} P_{F,t}^i} \right)^{-\gamma} C_{F,t}^i \quad (J.4)$$

From (3.1.9) the optimal consumption of imported goods can be expressed as:



$$C_{F,t}^i = \alpha \left( \frac{P_{F,t}^i}{P_t^i} \right)^{-\nu} C_t^i \quad (J.5)$$

Combining (J.3, J.4 & J.5) sing the demand functions the above can be expressed as:

$$C_{H,t}^i(j) = \left( \frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\varepsilon} \left( \frac{P_{H,t}}{e_{i,t} P_{F,t}^i} \right)^{-\gamma} \alpha \left( \frac{P_{F,t}^i}{P_t^i} \right)^{-\nu} C_t^i \quad (J.6)$$

$$Y_t(j) = \left( \frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\varepsilon} \left\{ (1-\alpha) \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} C_t + \int_0^1 \alpha \left[ \frac{P_{H,t}}{e_{i,t} P_{F,t}^i} \right]^{-\gamma} \left( \frac{P_{F,t}^i}{P_t^i} \right)^{-\nu} C_t^i di \right\} \quad (3.1.4)$$

Plug(3.1.49) into the aggregate output equation  $Y_t \equiv \left[ \int_0^1 Y_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}}$

$$Y_t \equiv \left[ \int_0^1 \left( \frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\varepsilon} \left\{ (1-\alpha) \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} C_t + \int_0^1 \alpha \left[ \frac{P_{H,t}}{e_{i,t} P_{F,t}^i} \right]^{-\gamma} \left( \frac{P_{F,t}^i}{P_t^i} \right)^{-\nu} C_t^i di \right\}^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (J.7)$$

$$Y_t \equiv \left[ \int_0^1 \left( \frac{P_{H,t}(j)}{P_{H,t}} \right)^{1-\varepsilon} dj \right]^{\frac{\varepsilon}{\varepsilon-1}} \left[ (1-\alpha) \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} C_t + \int_0^1 \alpha \left[ \frac{P_{H,t}}{e_{i,t} P_{F,t}^i} \right]^{-\gamma} \left( \frac{P_{F,t}^i}{P_t^i} \right)^{-\nu} C_t^i di \right] \quad (J.8)$$

$$Y_t \equiv \left[ (1-\alpha) \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} C_t + \alpha \int_0^1 \left[ \frac{P_{H,t}}{e_{i,t} P_{F,t}^i} \right]^{-\gamma} \left( \frac{P_{F,t}^i}{P_t^i} \right)^{-\nu} C_t^i di \right] P_{H,t}^{\varepsilon} \int_0^1 \left( \frac{P_{H,t}(j)}{P_{H,t}} \right)^{1-\varepsilon} dj \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (J.9)$$

$$Y_t = \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} \left[ (1-\alpha) C_t + \alpha \int_0^1 \left[ \frac{e_{i,t} P_{F,t}^i}{P_{H,t}} \right]^{\gamma-\nu} \left( \frac{P_{F,t}^i}{P_t^i} \right)^{-\nu} C_t^i di \right] \quad (J.10)$$

The real exchange is defined as  $\left( \frac{e_{i,t} P_{F,t}^i}{P_t} \right)$  which is equivalent of  $\left( \frac{P_{F,t}^i}{P_t^i} \right)$  but given

that the CPI is instead for country (i) thus the real exchange rate can be expressed as

$$(Q_{i,t})^\varepsilon.$$

$$Y_t = \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} \left[ (1-\alpha)C_t + \alpha \int_0^1 \left[ \frac{e_{i,t} P_{F,t}^i}{P_{H,t}} \right]^{\gamma-\nu} (Q_{i,t})^\nu C_t^i di \right] \quad (J.1)$$

Substitute  $(S_{i,t})$  for  $\left( \frac{P_{F,t}^i}{P_{H,t}} \right)$  the bilateral terms of trade; and  $(S_t^i)$  for  $\left( \frac{e_{i,t}}{P_{H,t}} \right)$

the effective terms of trade.

$$Y_t = \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} \left[ (1-\alpha)C_t + \alpha \int_0^1 [S_t^i S_{i,t}]^{\gamma-\nu} (Q_{i,t})^\nu C_t^i di \right] \quad (J.12)$$

$$Y_t = \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} C_t \left[ (1-\alpha) + \alpha \int_0^1 [S_t^i S_{i,t}]^{\gamma-\nu} (Q_{i,t})^{\nu-\frac{1}{\sigma}} di \right] \quad (J.13)$$

Assume  $S_{i,t} di = 0$

$$Y_t = \left[ \frac{P_{H,t}}{P_t} \right]^{-\nu} C_t \left[ (1-\alpha) + \alpha \int_0^1 [S_{i,t}]^{\gamma-\nu} (Q_{i,t})^{\nu-\frac{1}{\sigma}} di \right] \quad (J.14)$$

Log linearize around the steady state

$$Y_t \approx y - \nu \left( \frac{p}{p} \right)^{-\nu} \frac{1}{p} C \left[ (1-\alpha) + \alpha \int_0^1 (S_{i,t})^{\gamma-\nu} Q_{i,t}^{\nu-\frac{1}{\sigma}} di \right] \quad (J.15)$$

$$y_t = c_t + \alpha \gamma s_t + \alpha \left( \nu - \frac{1}{\sigma} \right) q_t \quad (J.16)$$

Insert the real exchange rate (3.1.27) into the equation above.

$$y_t = c_t + \alpha \gamma s_t + \alpha \left( \nu - \frac{1}{\sigma} \right) (1-\alpha) s_t \quad (J.17)$$

$$y_t = c_t + \alpha \frac{[\sigma \gamma + \sigma \nu (1-\alpha) - (1-\alpha)]}{\sigma} s_t \quad (J.18)$$

$$y_t = c_t + \frac{\alpha \varpi}{\sigma} s_t \quad (3.1.9)$$

$$\varpi \equiv \sigma \gamma + (1-\alpha)(\sigma \nu - 1) \quad (J.19)$$

For a generic country  $i$  (3.1.52) can be written as  $y_t^i = c_t^i + \frac{\alpha\varpi}{\sigma} s_t^i$

Aggregating over all countries we derive the world market clearing condition.

$$y_t^* \equiv \int_0^1 y_t^i di = \int_0^1 \left( c_t^i + \frac{\alpha\varpi}{\sigma} s_t^i \right) di = \int_0^1 c_t^i di + \frac{\alpha\varpi}{\sigma} \int_0^1 s_t^i di = \int_0^1 c_t^i di \equiv c_t^* \quad (3.1.5)$$

$$y_t = c_t^* + \frac{1-\alpha}{\sigma} s_t + \frac{\alpha\varpi}{\sigma} s_t \quad (3.1.6)$$

Substitute  $c_t^*$  for  $(y_t^*)$  as in (3.1.53)

$$y_t = y_t^* + \frac{1-\alpha}{\sigma} s_t + \frac{\alpha\varpi}{\sigma} s_t \quad (J: 20)$$

$$y_t = y_t^* + \frac{\frac{1}{\sigma}}{1+\alpha(\varpi-1)} s_t \quad (J: 21)$$

$$y_t = y_t^* + \frac{1}{\sigma_\alpha} s_t \quad (3.1.7)$$

$$\sigma_\alpha \equiv \frac{\sigma}{1+\alpha(\varpi-1)} \quad (J: 22)$$

$$y_t = E_t y_{t+1} - \frac{1}{\sigma} (i_t - E_t \pi_{t+1} - \rho) - \frac{\alpha\varpi}{\sigma} \Delta E_t s_{t+1} \quad (3.1.8)$$

$$y_t = E_t y_{t+1} - \frac{1}{\sigma} (i_t - E_t \pi_{Ht+1} - \rho) - \frac{\Theta}{\sigma} \Delta E_t s_{t+1} \quad (3.1.9)$$

$$\Theta = \sigma\gamma - 1 + (1-\alpha)(\sigma\nu - 1)$$

$$y_t = E_t y_{t+1} - \frac{1}{\sigma} (i_t - E_t \pi_{Ht+1} - \rho) - \frac{\Theta}{\sigma} \sigma_\alpha E_t \left\{ (y_{t+1} - y_{t+1}^* - y_t - y_t^*) \right\}$$

$$y_t = E_t y_{t+1} - \frac{1}{\sigma_\alpha} (i_t - E_t \pi_{Ht+1} - \rho) + \frac{\Theta}{\sigma_\alpha} \Delta E_t y_{t+1}^* \quad (3.1.10)$$

The Trade Balance

Defining the net exports as the difference between total production and total consumption in relation to the steady state output  $Y$  :

$$nx_t \equiv \frac{y_t - \frac{P_t}{P_{H,t}} c_t}{Y} \quad (3.1.6)$$

A first order approximation around a symmetric steady state

$$nx_t \approx \frac{Y - \frac{P}{P} Y}{Y} + \frac{1}{Y} \left[ (Y_t - Y) - \frac{P}{P} (C_t - C) - \frac{1}{P} C (P_t - P) + \frac{1}{p^2} PC (P_{H,t} - P) \right] \quad (J.23)$$

$$nx_t = \frac{Y_t - Y}{Y} - \frac{C_t - C}{C} - \frac{P_t - P}{P} + \frac{P_{H,t} - P}{P} \quad (3.1.6)$$

$$nx_t = y_t - c_t - p_t + p_{H,t} \quad (3.1.6)$$

$$nx_t = y_t - c_t - \alpha s_t \quad (3.1.6)$$

$$nx_t = \frac{\alpha \varpi}{\sigma} s_t - \alpha s_t \quad (3.1.6)$$

$$nx_t = \alpha \left( \frac{\varpi}{\sigma} - 1 \right) s_t \quad (3.1.6)$$

Equilibrium- Marginal cost and Inflation dynamics

Market clearing in the labor market requires

$$N_t = \int_0^1 N_t(j) dj \quad (J.24)$$

$$N_t(j) = \left( \frac{Y_t(j)}{A_t} \right) \quad (J.25)$$

Substituting the market clearing condition and the domestic consumption demand into (3.1.39)

$$N_t = \left( \frac{Y_t(j)}{A_t} \right) dj \quad (J : 26)$$

$$N_t = \left( \frac{Y_t}{A_t} \right) \int_0^1 \left( \frac{P_{H,t}(j)}{P_t} \right)^{-\varepsilon} dj \quad (J : 27)$$

$$n_t = y_t - a_t + d_t \quad (J : 28)$$

$$\text{where } d_t = \ln \left[ \int_0^1 \left( \frac{P_{H,t}(j)}{P_t} \right)^{-\varepsilon} dj \right] = 0 \quad \text{up to first order approximation.}$$

Thus the relation between employment, technology and output can be written as:

$$y_t = a_t + n_t \quad (3.1.6)$$

The domestic inflation is given by

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \frac{(1-\omega_H)(1-\beta\omega_H)}{\omega_H} mc_t \quad (J : 29)$$

$$\text{where } \lambda_H = \frac{(1-\omega_H)(1-\beta\omega_H)}{\omega_H} \quad (J : 30)$$

$$mc_t = -o + (w_t - p_t) + (w_t - p_{H,t}) - a_t \quad (J : 31)$$

$$mc_t = -o + \sigma \left( c_t^* + \frac{1-\alpha}{\sigma} s_t \right) + \eta (y_t - a_t) + \alpha s_t - a_t \quad (J : 32)$$

$$mc_t = -o + \sigma y_t^* + \eta y_t + s_t - (1+\eta) a_t \quad (3.1.8)$$

$$mc_t = -o + \sigma y_t^* + \eta y_t + \sigma_\alpha (y_t - y_t^*) - (1+\eta) a_t \quad (J : 33)$$

$$= -o + (\sigma_\alpha + \eta) y_t + (\sigma - \sigma_\alpha) y_t^* - (1+\eta) a_t \quad (3.1.9)$$

In flexible price ( $y_t^n$ ) and the marginal costs is ( $mc = -\mu$ ). Thus (3.1.69) can be written as:

$$m_c = -\mu = -o + (\sigma_\alpha + \eta) y_t^n + (\sigma - \sigma_\alpha) y_t^* - (1 + \eta) a_t \quad (3.1.7)$$

$$y_t^n = \frac{o - \mu}{\sigma_\alpha + \eta} + \frac{1 - \eta}{\sigma_\alpha + \eta} a_t - \frac{\sigma - \sigma_\alpha}{\sigma_\alpha + \eta} y_t^* \quad (J: 34)$$

Using  $\left( \sigma_\alpha \equiv \frac{\sigma}{1 + \alpha \Theta} \right)$

$$y_t^n = \frac{o - \mu}{\sigma_\alpha + \eta} + \frac{1 + \eta}{\sigma_\alpha + \eta} a_t - \frac{\sigma \frac{(1 + \alpha \Theta) - \sigma}{1 + \alpha \Theta}}{\sigma_\alpha + \eta} y_t^* \quad (J: 35)$$

$$y_t^n = \Gamma_0 + \Gamma_a a_t + \Gamma_* y_t^*; \quad (3.1.8)$$

where,  $\Gamma_0 \equiv \frac{o - \mu}{\sigma_\alpha + \eta}, \Gamma_a \equiv \frac{1 - \eta}{\sigma_\alpha + \eta} a_t > 0, \Gamma_* \equiv -\frac{\alpha \Theta \sigma_\alpha}{\sigma_\alpha + \eta} y_t^*$  (J: 36)

### The New Keynesian Phillips curve

Defining  $\tilde{y}_t \equiv y_t - y_t^n$  as the domestic output gap. The real marginal cost gap is derived by subtracting (3.1.69) from (3.1.70).

$$mc_t = (\sigma_\alpha + \eta) \tilde{y}_t \quad (J: 37)$$

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \kappa_\alpha \tilde{y}_t; \quad (3.1.9)$$

$$\kappa_\alpha = \lambda_H (\sigma_\alpha + \eta)$$

## The Dynamic IS Equation/Output gap

Defining the real interest rate as  $r_t \equiv i_t - E_t \pi_{t+1}$  and insert into (3.1.59)

$$y_t = E_t y_{t+1} - \frac{1}{\sigma_\alpha} (r_t - \rho) + \alpha \Theta \Delta E_t y_{t+1}^* \quad (3.1.76)$$

Define the natural output as

$$y_t^n = E_t y_{t+1} - \frac{1}{\sigma_\alpha} (r_t^n - \rho) + \alpha \Theta \Delta E_t y_{t+1}^* \quad (3.1.77)$$

Subtract (3.1.76) from (3.1.77)

$$\tilde{y}_t = E_t \tilde{y}_{t+1} - \frac{1}{\sigma_\alpha} (i_t - E_t \pi_{t+1} - r_t) \quad (3.1.78)$$

Solving for the real interest rate.

$$E_t \Delta y_{t+1} = \frac{1}{\sigma_\alpha} (i_t - E_t \pi_{t+1} - \rho) - \alpha \Theta E_t \Delta y_{t+1}^* \quad (J: 38)$$

$$\frac{1}{\sigma_\alpha} (i_t - E_t \pi_{t+1} - r_t) = E_t \Delta \tilde{y}_{t+1} \quad (J: 39)$$

$$r_t = (i_t - E_t \pi_{t+1}) - \sigma_\alpha E_t \Delta \tilde{y}_{t+1} \quad (J: 40)$$

$$r_t = (i_t - E_t \pi_{t+1}) - \sigma_\alpha \left[ E_t (y_{t+1} - y_{t+1}^n) - (y_t - y_t^n) \right] \quad (J: 41)$$

$$r_t = (i_t - E_t \pi_{t+1}) - \sigma_\alpha \left[ \left( \frac{1}{\sigma_\alpha} (i_t - E_t \pi_{t+1} - \rho) - \alpha \Theta E_t \Delta y_{t+1}^* \right) \right. \\ \left. - \Gamma_a E_t \Delta a_{t+1} + \Gamma_* E_t \Delta y_{t+1}^* \right] \quad (J: 42)$$

$$r_t = \rho + \sigma_\alpha \Gamma_a (\rho_a a_t - a_t) + \sigma_\alpha \left( \frac{\alpha \Theta (\sigma_\alpha + \eta) - \alpha \Theta \sigma_\alpha}{\sigma_\alpha + \eta} \right) E_t \Delta y_{t+1}^* \quad (J: 43)$$

$$r_t = \rho - \sigma_\alpha \Gamma_a (1 - \rho_a) a_t + \sigma_\alpha + \frac{\alpha \Theta \sigma_\alpha \eta}{\sigma_\alpha + \eta} E_t \Delta y_{t+1}^* \quad (3.1.79)$$

The End.

## **Chapter 4 Monetary policy rules in developing countries (A case study of Botswana, Brazil, Chile, Namibia, Peru, Philippine, South Africa and Thailand).**

This chapter empirically examines whether developing countries observe the Taylor rule in setting their interest rates or responds to changes in international interest rates (US interest rate). Its trajectory is as follows. Section 4.0 presents the introduction and the literature review. The estimated monetary policy reaction function is presented in 4.1, the econometric methodology follows in 4.2. The chapter uses the GMM econometric procedure to estimate the monetary policy rule(s). In addition the Hodrick-Prescott method is used to filter the data. Section 4.3 discusses the data, sources and the transformations. Section 4.4 to 4.11 presents the monetary policies followed in each country and discusses the estimation results, 4.12 conclude.

### **4.0 Introduction**

In recent years, there has been an increased interest to compare how central banks actually set their policy rates against the prediction of the Taylor rule which was first proposed in 1993. The rule recommends that interest rates should be altered taking into account the deviation of inflation from a target as well as the output gap. The need for increased monetary discipline in developing market economies has been advanced given their relatively high inflation and low policy credibility. For instance, Calvo and Mishkin (2003) discuss why developing market economies are susceptible to “sudden stops” of capital inflows and frequent collapse of the exchange rate. They attribute such crises in developing market economies to weak institutional credibility. Thus, they suggest that central banks in developing economies should adopt inflation targeting (IT) which would make it harder to follow an “overly expansionary monetary policy”.

Taylor (2002) recommends emerging economies to adopt rule based monetary policies. He contends that following a systematic approach in setting interest rates would enhance the probability of economic agents anticipating the effects of monetary policy. Thus, the increased predictability of the central bank behaviour is expected to amplify the



transmission and effectiveness of monetary policy. Taylor (2002) recommendations seem to be the path adopted by an increasing number of central banks in developing economies in the last two decades. For instance, Paez-Farrell (2007) contends that the methods and conduct of monetary policy tend to have converged, with many developing countries adopting an explicit or implicit inflation targeting framework. Moreover Maria-Dolores (2005) states that a number of developing countries have implemented market oriented instruments such as short term interest rates. This is also evident in our sample given that all the countries selected use the short term interest rate as a tool for monetary policy while six have introduced inflation targeting. Despite, for the increase in the number of developing countries using market oriented instruments, the empirical evidence on the significance of interest rate rules in these countries remains limited and a very recent phenomenon. This can be ascribed to the nascence of central bank independence in developing countries.

A few recent studies on developing economies however contain imperative findings. In a study involving East Asian countries, the Monetary Authority of Singapore (2000) concludes that following the adoption of inflation targeting, countries in East Asia now put more emphasis on controlling inflation as well as setting the interest rate taking into account the expected inflation. Filosa (2001) finds that emerging market economies tend to respond strongly to the exchange rate; however the study did not examine the importance which these countries attach to price stability. In particular, he estimates The Taylor rule type for countries such as Brazil, Chile, Mexico, Peru, Korea and Malaysia using data from 1980 to 1999. Among other things he shows the following: (1) The estimated monetary policy function in Chile, Mexico, Korea and Malaysia is similar to the Taylor rule. (2) Monetary policy did not accommodate inflation in Chile and Malaysia, while it was accommodative in Mexico and Korea. (3) The Taylor rule is incapable of explaining the short-term interest rate behaviour of Brazil and Peru. (4) Monetary authorities reacted strongly to changes in the exchange rate in all countries reviewed.

Similarly, Corbo (2002) concludes that Latin American countries tend to consider other objectives apart from inflation when setting their interest rates. He examines monetary policy rules for five countries namely Chile, Colombia, Costa Rica, El Salvador and Peru using quarterly data from 1990 to 1999. In addition to the Taylor rule, he includes other objectives which the respective central bank articulates in their policy documents. His results can be summarised as follows: For Chile, interest rates are determined by the inflation gap and the current account gap. The output gap is insignificant in the reaction function of the central bank. The coefficient on the inflation gap is less than unity.

The interest rate in Colombia, responds to changes in inflation, unemployment rate and exchange rate, with the inflation coefficient less than unity. For Costa Rica, the interest rate responds to inflation (coefficient less than one) and the output gap. The results for Peru show that the concern of the monetary authority during this period includes the stabilisation of inflation, output gap and exchange rate. Similar to other countries the central bank accommodates inflation. In Africa, Boamah (2012) concludes that the estimated Taylor rule for Ghana suggests a weak relationship between the policy rate and inflation. Thus the results imply that the central bank of Ghana was expansionary in the period between 1993 to 2011.

Moreover, it is often argued that changes in interest rates in major countries tend to have imperative consequences on other countries. For instance, the 1999–2000 hikes in U.S. interest rates were replicated in interest rate increases in other industrial and developing economies (Frankel et al. 2004). This episode has also been true in past global monetary tightening<sup>31</sup>. Additionally, there exists “fear of floating” which prevents countries from allowing the exchange rate to move freely (Calvo and Reinhart, (2000, 2001 and 2002) and Hausmann et al. (2001). Calvo and Reinhart (2000) suggest that the dynamics of some critical variables of emerging economies shows that they try to intervene in order to minimise exchange rate volatility. They document evidence from a number of emerging countries, which can be summarised as:

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<sup>31</sup> Frankel et al (2004) argues further that in developing economies for instance such episodes were proportionally larger than those experienced in the U.S. This can be attributed to the currency risks associated with the rise in the Fed funds rate.

- (a) the exchange rate variability of these economies is lower compared to true floaters.
- (b) the foreign reserves variability is high, implying that policy makers in emerging markets tend to lean against the wind through interventions in the foreign exchange markets.
- (c) the short-term interest rates volatilities is high, signifying that monetary policy reacts to exchange rate changes.
- (d) the correlation between the exchange and interest rates is positive, which they interpret to mean that the central banks respond to exchange rates.

There are three main reasons why emerging economies might evade excessive exchange rate fluctuations. First, the pass-through of devaluation is considered to be large in emerging economies (Ortiz, 2000). Second, devaluation may deteriorate the balance sheets of both banks and firms (Filosa, 2001). Therefore, substantial fluctuations in the exchange rate may cause financial crises and profound recessions, in addition to inflation. Third, for countries with a large external debt, devaluation may deteriorate the fiscal position of the country at large. Hence, many countries despite the kind of exchange rate regime are technically “importing” the monetary policy of major-countries, much as those with pegs. Frankel et al (2004) suggests that interest rates in developing countries with flexible exchange rates might sometimes be more responsive to the U.S. interest rates than countries with fixed-exchange rates.

A peculiar characteristic of the existing literature illustrates that most researchers tend to focus on either individual country or regional experiences. The exception is Filosa, (2001) who examines the interest setting of developing countries across two regions. This chapter studies the interest rate behaviour of three regions (Latin America, East Asia and Southern Africa, using data from 1999 to 2010. Also, the countries selected in East Asia in this chapter are different to those of Filosa (2001). The chapter’s intention is to obtain some preliminary evidence about interest rate setting behaviour in developing

economies. More particularly, it tends to determine whether developing countries in the sample take into account developments in the US interest rate when setting their monetary policies. To answer this question the chapter estimates the Taylor rule which includes the US interest rate as an additional variable in addition to the forecasted domestic inflation and the output and past interest rate. Before estimation however, I provide the motivation for the proposed monetary policy reaction function.

#### **4.1 The monetary policy reaction function**

The framework I set up is relevant for a central bank which has autonomy to determine the direction of its monetary policy. This tends to fit well with the countries in the sample, given that seven of them have flexible exchange rates, and hence have control over domestic monetary policy formulation. The policy reaction function assumes the existence of short run or temporal nominal rigidities in the form of prices or wages. With nominal rigidities, the monetary authority affects the real interest rate and the real exchange rate by varying the nominal interest rate. Despite that there is a debate over the details, imperfect prices and wages bring about a positive short-run relationship between output and inflation. This short run trade-off may constrain how the monetary authority manages its policy given that reducing inflation may entail output reduction, depending on the intensity of nominal stickiness.

As in Clarida et al. (1998), we assume that the central bank uses the bank rate as the operating instrument of monetary policy. Their policy rule is a generalisation of the backward looking Taylor 1993 rule in which the central bank responds to forecasted inflation and output rather than past inflation. In the case of the Taylor 1993 rule, relevant explanatory variables may be omitted from the interest rate rule. In case where some of those variables are correlated with the error term, the orthogonality conditions will be violated and thus leading to the rejection of the model asymptotically. By incorporating expected inflation the reaction function makes it possible to link the estimated coefficients and the objectives of the central bank. Moreover, assuming that the central bank respond to forecasts of inflation and output ensure that we incorporate a realistic

feature of central banks, that it takes into account a wide-range of information. Furthermore, we believe that policy makers are more concerned about medium and longer-term trends in inflation and thus a quarter ahead forecasts seems to be a good indicator of medium term trend in inflation. I however, make two modifications to their rule: First I replace the output with the expected output as in Javanovic and Petreski (2012). Second I include the U.S. interest rate, to test the claim by Frankel et al (2004) that interest rates in developing countries with flexible exchange rates might sometimes be more responsive to the U.S. interest rates in addition to domestic economic considerations. The resultant monetary policy function is as follows:

$$i_t = \phi_0 + \phi_1 i_{t-1} + \phi_2 USrate_t + \phi_3 E(\pi_{t+1}) + \phi_4 E(y_{t+1}) + u_t, \quad (4.1)$$

where  $i$  is the nominal interest rate,  $i_{t-1}$  represent the interest smoothing term,  $\phi_1 \in [0,1]$ . The reasons for smoothing interest rate changes include the fear of loss of credibility which might be sparked by large policy reversals, the need for consensus building to support a change in policy and fear of disrupting capital markets.  $\pi_{t+1}$  is the expected inflation and  $y_{t+1}$  is the expected output. If the coefficient  $\phi_3 > 1$ , the target real interest rate changes to stabilise inflation and the output (assume  $\phi_4 > 0$ ). Alternatively, when  $\phi_3 < 1$ , it moves to accommodate deviations in inflation. Despite, for the central bank increasing the nominal interest rate in response to a rise in inflation, it does not increase it very much to prevent the real interest rate from declining.  $USrate_t$  stand for the U.S.interest rate, while  $u_t$  is the exogenous random shock to the interest rate, assumed to be i.i.d. Furthermore, I modify(4.1)by including the interest rate for South Africa and use it to estimate the Taylor rule for Namibia. This is due to the fixed exchange rate between the two countries. The resultant Forward lookingTaylor equation for Namibia can be expressed as:

$$i_t = \phi_0 + \phi_1 i_{t-1} + \phi_2 USrate_t + \phi_3 \pi_{t+1} + \phi_4 y_{t+1} + \phi_5 SARate_t, \quad (4.2)$$

## **4.2 Methodology**

### **4.2.1 Econometric procedure**

The equations (4.1) and (4.2) were estimated by the Generalised Method of Moments (GMM) developed by Hansen (1982) to mitigate endogeneity in the variables which might cause inconsistency in ordinary least squares (OLS). Endogeneity refers to the scenario where some or all explanatory variables may be determined by the dependent variable(s) or where a shock might affect both the dependent and independent variable. For instance a shock which affects the nominal interest rate might have similar effect on inflation given that the two variables are linked up through the Fisher's equation. In this case the assumption that the estimators are exogenous (i.e.) determined outside the model is violated.

Consequently, the assumption of zero conditional mean may not hold. Using OLS in this case makes the estimates inconsistent and thus produces spurious regression results. To account for this problem, the common modus operandi in the literature is to use the General Methods of Moments–Instrumental Variable (GMM-IV) estimation approach. This approach entails that to obtain GMM estimate, we must write the moment conditions as orthogonality condition between the residuals and instrumental variables. That is we have to choose instrumental variables which are strongly correlated with the explanatory variables of the model (right hand side variables) but not correlated with the residuals. As for the instrumentation I used lagged values of the regressors. This approach is commonly used in the New Keynesian literature, for instance Clarida et al. (1998 p. 1044) uses four lagged values of the regressors to instrument for the expected inflation and output in the reaction function of Germany, Japan and USA.

This kind of instrumentation is acceptable as long as the error term is not correlated with past values of the regressors (Javanovic and Petreski, 2012). Using lags for monetary policy implies that the central bank is forward looking (rational), given that lags serve as

indicators of future values (Tchaidze and Carare, 2005). It also suggests that the central bank take into account all available information when making monetary policy decisions. Consequently, forecast errors are not correlated with available information (Boivin, 2006 and Clarida et al. 2000). The Forward looking Taylor rule(s) were estimated country by country as in Clarida et al. (1998), using Eviews 6. I also selected four lags of the regressors as instruments similar to (Clarida et al. 2000). The validity of the instruments was checked with the J statistic. As for the Weighting Matrix: I selected the Time series (HAC), to ensure that the GMM estimates were robust to heteroskedasticity and autocorrelation of unknown form.

After estimating the baseline Forward looking Taylor rules (4.1) and (4.2), I extend the analysis to a case where the central bank have pursued policies to maintain exchange rates within reasonable bounds, while retaining some degrees of monetary controls. This scenario may best describe the monetary policy formulation of central bank of Peru. In this case, the exchange rates may have influenced monetary policy independent of the information they possess about inflation and output. Including the exchange rate in the baseline model also serves as a robust check measure intended to verify whether the baseline results holds in the presence of additional parameters. I estimate the alternative model in the same way as the baseline, however I expand the parameter vectors to include the coefficient of the exchange rate and expand the instrument list to include lagged values of the exchange rate.

#### 4.2.2. The Hodrick-Prescott (HP) Filter

In this section I describe the method which was used to decompose series into a trend and stationary components<sup>32</sup>. Hodrick and Prescott (1997) developed a linear filter which computes the smoothed series of  $x_t$  of  $y_t$  by minimizing the variance of  $y_t$  around  $x_t$  taking into account a penalty that limits the second difference of  $x_t$ . The HP-filter is one of the measures used to obtain cyclical movements about the trend in

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<sup>32</sup> I used this method to create the gaps of the variables.

macroeconomic time series variable. The underlying assumption for this filtering method is that the non-stationary fluctuations in a time series are captured by its smooth as well as the slow moving trend. One of the reasons contributing to its popularity as a detrending tool is its simplicity as well as its ease of use. The filter's other beauty is its ability to capture and slowly track the changing trends of the long term economic behaviour of the variable as well as its usefulness to measure business cycles. For example, suppose the series  $y_t$  consist of a trend component  $x_t$  and a cyclical component  $c_t$ :

$$y_t = x_t + c_t \quad (4.3)$$

To isolate the cyclical component, the HP Filter minimizes:

$$\sum_{t=1}^T (y_t - x_t)^2 + \lambda \sum_{t=2}^{T-1} [(x_{t+1} - x_t) - (x_t - x_{t-1})]^2; \quad (4.4)$$

where  $T$  represents the number of observations while  $\lambda$  is a penalty or trade-off parameter. Accordingly, (4.4) has two different terms, the first term serves as a measure of fitness of the time series, while the second is a measure of smoothness. Thus similar to many other smoothing measures the HP Filter entails a trade-off between goodness of fit and smoothness. The larger the penalty parameter, the smoother the series. For instance when the value of  $\lambda = 0$ , the series will be equal to the original series. In contrast as  $\lambda$  diverges towards infinity the series approximates a linear trend. For quarterly data it is suggested to use a value of  $\lambda = 1600$ .

### 4.3 Data, sources and transformations.

I used quarterly data for the period beginning 2000 to 2012, when most of the countries in the sample migrated to inflation targeting<sup>33</sup>. The only exceptions were Botswana and

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<sup>33</sup> Brazil, 15 July 1999; The Phillipines, January 2000; Chile and Thailand, May 2000; South Africa, 2000; Peru 24 January 2002.



Namibia where the beginning period was 1999, when there was significant changes in monetary policies of those countries. The data were obtained from the International Financial Statistics (IFS) of the International Monetary Fund (IMF), apart from that of Namibia which I obtained from the Bank of Namibia. The data consisted of five variables: inflation, the output gap, interest rate, the US interest rate and the exchange rate. More specifically I used the consumer price index (CPI) per centage change as a measure of inflation, the industrial production seasonally adjusted as a proxy for output, the discount rate for the interest rate. The latter was due to the fact that not all countries report the bank rate. Also I used the market rate (US Dollar per national currency) as the measure of the exchange rate.

To derive the output gap I used the log of the seasonally adjusted industrial production obtained by the HP filter to create a potential output series. The output gap was then calculated as the difference between the log of the original series of the seasonally adjusted output and the potential output obtained from the HP filter. GMM requires data to be stationary, thus we initially examined the integration properties of the data. To induce stationarity, I followed (Javanovic and Petreski, 2012) and used the gap (cycle) of the variables<sup>34</sup>, obtained by the HP filter<sup>35</sup>. After filtering these variables became stationary (table 7-14). This approach is different from Clarida, Galí and Gertler (2000 p. 154) who treat the interest rate as a stationary variable even if the null of a unit root is hard to reject.

## **4.4 Botswana**

### **4.4.1 Monetary policy in Botswana**

Botswana became part of the Rand Monetary Area (RMA) subsequent to independence in 1966 along with Lesotho, Swaziland, Namibia (then South West Africa) and South

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<sup>34</sup> The exception is the output gap which is already stationary.

<sup>35</sup> This process is similar to the procedure which derived the output gap.

Africa. The RMA entailed using the South African rand as the common currency. Moreover, monetary policy was an exclusive mandate of the South Africa Reserve Bank (SARB). The Bank of Botswana (BoB) was established in 1976, primarily to conduct monetary and exchange rate policy given a rise in export revenue. Therefore, monetary policy regimes in Botswana can be dichotomised into two main regimes.

The first regime covers the period 1976 to 1989. The monetary policy goals of the first regime were monetary stability and economic growth. During the first regime the BoB used direct tools of monetary policy such as regulating the borrowing and lending interest rates, credit limits and required reserves. Furthermore, the exchange rate was often used to achieve competitiveness as well as to reduce the impact of imported inflation. The significance of interest rate as a monetary policy tool was minimal, given that they were kept low to encourage investment.

However the increase in financial flows primarily due to mining sector created a large current account surplus and excess liquidity in the financial system. The latter made the monetary policy tools blunt. For example, commercial banks held high reserves exceeding the minimum legal reserve requirement of the BoB, thus rendering the reserve ratio ineffective. On the other hand, the low levels of interest rate encouraged excessive borrowing for unproductive investment and consumption (Bank of Botswana, 2005). Consequently inflation increased to double digit levels, while the real interest rate tended to be very low and sometimes negative thus discouraging financial savings.

The use of the exchange rate as a tool to control inflation and promote competitiveness also created a conflict (Galebotswe and Tlhalefang, 2013). Accordingly, a depreciation of the exchange rate improved the competitiveness of exports and increased imported inflation. In the beginning of 1990, a second regime was introduced following the recommendations of a joint study of the Bank of Botswana and the World Bank (Galebotswe and Tlhalefang, 2013).

The second regime was characterised by the removal of credit controls and interest rate ceilings as well as abandonment of the use of the exchange rate. Besides, the focus of monetary policy also changed towards the maintenance of price stability. In 1991, the BoB introduced indirect monetary policy tools such as the central bank rate and open market operations (OMO). The former comprised of auctioning of the 14-day and 91-day Bank of Botswana certificates (BoBCs) on a weekly and monthly basis primarily to mop up excess liquidity from the financial system. Unlike in the first regime, the lending and deposit interest rates of commercial banks were determined by demand and supply forces.

The central bank rate served as the signal for the future course of the market interest rates; however the auctioning of the BoBCs was the main operational instrument of monetary policy. In 1998, a monetary policy committee (MPC) was set up to oversee the conduct of monetary policy of the Bank. The committee meets 6 times a year and publishes an annual Monetary Policy Statement (MPS). The latter is a transparent framework describing the conduct of monetary policy in Botswana. The BOB sets the central bank rate given its assessment of the economy.

In 2002, the Central Bank announced for the first time its inflation objectives. Accordingly, the BOB announced an annual inflation target of between 4-6 per cent. Galebotswe and Tlhalefang 2013, states that the objective was specified as an annual average of 12 month changes in the Consumer Price Inflation (CPI). However, the focus of the Central Bank is on “core inflation” excluding the prices of fuel and administered prices which are considered to be highly volatile (Bank of Botswana, 2010). In 2006, the Central Bank increased the horizon for the annual inflation target to 4-7 per cent and introduced a medium term (3 year horizon) target of 3-6 per cent. Furthermore, BoB decided to restrict the purchase of BoBCs to commercial banks only in 2006. In the middle of 2008, BoB abandoned the annual inflation targets arguing that price stability can be achieved reasonable in the medium term. According to Bank of Botswana (2010),

the indirect tools improved the role of interest rates in the monetary transmission process.

#### **4.4.2 Results of the Forward looking Taylor rule**

Economic literature posits a positive correlation between the interest rate, the output gap and the international interest rate. The intuition is that the central bank increases its interest rate when either of the variables increases and vice versa. On the contrary the literature postulates a negative relationship between the central bank interest rate and the exchange rate, i.e. the central bank lowers its interest rate when the exchange rate rate appreciates and vice versa.

The results of the estimated Forward looking Taylor rule suggest that the interest rate in Botswana responds to the U.S. interest rate, past interest rates and expected inflation (table 15). Other things being equal an increase in the U.S. interest rate of about 1 per cent causes an increase in the Botswana interest rate of about 0.10 basis points. Similarly, an increase in inflation of about 1 per cent induces the central bank to hike the interest rate by about 0.07 basis points *ceteris paribus*. The coefficient of the expected inflation parameter was however less than unity which is prescribed by the Taylor Principle. This tends to suggest that monetary policy in Botswana was expansionary during the period under review.

Moreover, the estimated Forward looking Taylor rule shows that the Bank of Botswana changed interest rate smoothly with the smoothing parameter estimated at 0.7 per cent. The expected output gap was insignificant despite displaying the expected sign. The latter can be explained by the fact that developing countries tend to react to supply shocks rather than demand shocks. The explanatory power of the equation was very high with the adjusted Rsquared of 74 per cent. The J-statistic of 9.15 with the probability of 0.68 does not reject that the overidentifying restrictions were satisfied.

The results from the estimated Forward looking Taylor rule augmented with the exchange rate tend to confirm that interest rate in Botswana respond to variations in the U.S. interest rates (table 16). The exchange rate appeared with the correct negative sign and significant. The central bank of Botswana tended to lean against the wind, i.e. raised the interest rate when the exchange rate depreciated. The explanatory power of the equation improved slightly to 79 per cent. Similarly, the J-statistic did not reject that the overidentifying restrictions were satisfied.

## **4.5 Brazil**

### **4.5.1 Monetary policy in Brazil**

The monetary policy in Brazil has a history of foremost changes in response to key developments in the economy. Price freezes and government intervention were some of the initial instruments used to stabilize the economy during the high inflation of the 1980s. However these measures proved futile. In 1993, Fernando Henrique Cardoso was appointed as the Minister of Finance with a mandate to control the hyperinflation in the economy. Working in collaboration with a team of economists, he fashioned and implemented the Real Plan<sup>36</sup> in 1994. To accomplish and maintain price stability, the Real Plan introduced a new currency which was pegged to the U.S. dollar. In addition, quarterly targets for the monetary aggregates were introduced while the exchange rate was allowed to float in July 1994. The former was aimed at inducing confidence in the economy by signalling that there would be no inflationary financing of the government deficit.

Furthermore, a policy of high interest rates was introduced giving rise to a significant inflow of foreign capital and subsequent appreciation of the currency. In December 1994,

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<sup>36</sup> A stabilisation plan consisting of the following: (1) A fiscal strategy which created the Social Emergency Fund and other long term reforms, (2) Monetary reforms which introduced a new unit of account which later became the national currency, (3) A “big bang” approach to liberalise the economy and the adoption of a new foreign exchange policy.

the Mexican currency crisis triggered outflow of capital from Latin American countries. This subsequently caused a significant reduction in foreign reserves which consequently increased the balance of payment problems in Brazil. In response to this development, Brazilian authorities introduced exchange rate bands which acted like a crawling peg in March 1995 (Otker-Robe and Vavra, 2007). This was intended to mitigate the exchange rate volatility brought about by the flexible exchange rate. In addition, the monetary authority increased the nominal interest rates and announced tariffs in specific sectors (Banomo and Terra, 2001). The increase in interest rate however raised the public debt obligations, worsened the fiscal deficit, and subsequently constrained growth and investment (Bulmer-Thomas, 1999).

The Brazilian fiscal position deteriorated further in 1998, due to the increase in the speculative attacks on the currency following the Russian crisis. On the 13 January 1999, the crawling peg arrangement was replaced with an exchange rate band with explicit rules of intervention, also known as “endogenous diagonal band” (Otker-Robe and Vavra, 2007). Following a very sharp depreciation however, the exchange rate was allowed to float on January 15, 1999. Brazil subsequently introduced Inflation Targeting (IT) in June 1999, replicating the British IT model. It comprises of the National Monetary Council (CMN) consisting of the Minister of Finance, Minister of Planning and the president of the BCB. The president of Brazil appoints all the members of the CMN. The role of the CMN is to among other things set the inflation targets, regulate the financial system as well as approve the main norms related to monetary and exchange rate policies. The Minister of Finance initially proposes the inflation targets.

In June of each year, the CMN set up the inflation targets as well as the corresponding tolerance level for the next two years. The inflation target is based on the extensive national consumer price index (IPCA). i.e. headline inflation index. However, there is a provision for the IT to vary within the range of between 2.0 or 2.5 per centage points above and below the central point target. The main reason for tolerating variations in bands is to help the Central Bank realise the set inflation target in the event of supply

shocks. The Central Bank of Brazil Monetary Policy Committee (COPOM) executes monetary policy.

When the inflation over or undershot the set target, the governor of the BCB is mandated to explain to the Minister of Finance. The explanation must include the reasons why the targets were missed and the measures put in place to bring it back to the target. The COPOM set the Selic interest rate (the interest rate for overnight interbank loans) which remains fixed between regular meetings. The committee publishes the minutes on the BCB website and to the press eight days after each meeting. Moreover, the COPOM publishes the BCB inflation report at the end of each quarter. The latter is intended to inform the public about the goals, design, and implementation of monetary policy.

Following the financial crises of 2008, the Central Bank of Brazil adopted quantitative easing measures to mitigate the effects of the crises. These measures were characterised by the auctioning of U.S. dollars with a plan to buy them back at a later date, loan reserve auctions and currency swap contracts. Consequently, the Central Bank injected R\$13.2 billion into the financial markets. By the end of October 2008, the value of the currency trade agreement between the FED and the BCB stood at US\$30 billion. Other initiatives involved freeing the mandatory reserves, easing credit rules and reduction of taxes on financial transactions (IOF).

#### **4.5.2 Results of the Forward looking Taylor rule**

The estimated Forward looking Taylor rule for Brazil states that the interest rate responded to the expected output gap and the U.S. interest rate (table 15). However, the U.S. interest rate appeared with a negative sign while the coefficient of the expected output gap was overstated. Surprisingly the coefficient of the expected inflation appeared with a wrong sign and insignificant. The degree of interest rate smoothing was 0.97 per cent. The estimated equation explained about 55 per cent of the changes in the Brazilian interest rate. The J–statistic again did not reject that the overidentifying restrictions were satisfied.

On the other hand, the Forward looking Taylor rule with the exchange rate tends to suggest that the bank rate in Brazil responded positively to the expected output gap and negatively to the exchange rate. The U.S. interest rate was significant but with a wrong sign, while the coefficient on the expected inflation appeared with the correct sign despite that it remained insignificant. The degree of interest rate smoothing was 0.83 per cent. The estimated equation explained about 52 per cent of the changes in the Brazilian interest rate. Similarly the J–statistic did not reject that the overidentifying restrictions were satisfied.

## **4.6 Chile**

### **4.6.1 Monetary policy in Chile**

The Central Bank of Chile (CBCh) pegged the exchange rate to the U.S. dollar in 1979, thus providing a nominal anchor for monetary policy. The fixed exchange rate regime was however abandoned in June 1982 subsequent to a major financial crisis attributed to a large shift in U.S. monetary policy. In August 1984 the exchange rate was floated within narrow bands. The latter gave the CBCh some room to undertake active monetary policy. In 1985 however, the constraints caused by the debt crisis rendered monetary policy ineffective. Consequently, balance of payments considerations prevailed over inflation or output stabilisation goals.

The Brady Plan<sup>37</sup> of 1989, which eased the external debt hangover in major economies of Latin America, brought hope and optimism in the financial markets in the early and middle 1990s. This was augmented by the recovery in global growth and commodity

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<sup>37</sup> A plan which was designed to address the debt crisis of the Least Developing Countries of the 1980's. The principles of the plan were first articulated by the U.S. Secretary of Treasury Nicholas F. Brady in March 1989. The debt crisis started in 1982, when a number of countries particularly in Latin America were unable to service commercial bank loans due to the high interest rates compounded by low commodity prices. Under the plan debtor countries and their commercial bank creditors engaged in rescheduling and restructuring of sovereign as well as private sector debt on the premises that the debt problem was a temporary phenomenon which would end when the economy rebound.



prices as well an accommodative<sup>38</sup> monetary policy stance of the U.S. Federal Reserve Bank. Consequently, there was a surge of capital flows in Latin American Economies. Laban and Larrain (1994) posit that Chile received the largest share of the private capital inflows as a per centage of GDP among the five biggest economies of Latin America in 1989 and 1990. In December 1989, the new Central Bank legislation was enacted with greater emphasis on the central bank independence and price stability. However, with the inflation rate in double digit figures by then, reducing it to single digit levels was considered the most pressing objective of the Central Bank.

The other challenge that confronted policy makers then was the need to reduce the inflow of foreign capital, necessitating economic authorities to deliberate various options at the time (Bianchi, 2009). As a solution, the Central Bank of Chile announced unremunerated reserve requirement on capital, known as the *encaje* inflows in June 1991. Accordingly, 20 per cent of certain capital inflows were deposited at the central bank in an account which earned no interest for the period of the investment or one year, whichever was deemed the shortest. The *encaje* was increased to 30 per cent in May 1992, and extended to cover a wide range of capital inflows. The objective of imposing a tax on foreign credit was to prevent the exchange rate from breaching the set bands as well as to pursue an independent monetary policy. Following a wave of financial liberalisation, the *encaje* was lowered further to 10 per cent in June 1998 before being abandoned in September.

Given the risk posed by the depreciation of the exchange rate, the Central Bank feared that the loss of a nominal anchor might transmit a severe depreciation path-through to inflation. Consequently, the bands were increased during the first half of 1999, before the exchange rate was floated in September the same year. The Central Bank further announced the migration to inflation targeting. The IT was however fully implemented in May 2000, when the CBCh formally adopted established procedures for regular

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<sup>38</sup> This was in response to the minor recession of the 1990 in the United States of America.

monetary policy meetings, forecasting tools and models. Moreover, the CBCh began publishing periodic inflation reports including explicit inflation forecasts.

Chile's inflation target since 2001 has been defined as a 2% to 4% target range, centred around 3% annual inflation. Monetary policy responds to the deviations between the CBCh's inflation forecast (and the gap between actual and potential output) from the 3% inflation target over the 24-month policy horizon. The operational target of the central bank is the overnight interest rate on interbank loans while the monetary policy instruments include standing facilities, the legal bank reserves and open-market operation (OMO).

The latter serves as the main instrument for managing liquidity together with repurchase and reverse-repurchase operations. Reserve requirements have not been changed since 1980 and hence not used as a monetary policy instrument. Within the IT regime, foreign exchange interventions have been restricted to cases where the real exchange rate diverted significantly from its equilibrium and considered as damaging to the economy. Thus far from September 1999 to date, foreign market operations were conducted four times in August 2001, October 2002, April 2008 and January 2011. The process of conducting foreign currency operations begins with the central bank announcing explicitly the quantities of the currency involved as well as the duration. Since 2007, the main monetary policy objective was to keep the annual CPI inflation at around 3% with the tolerance range of one per centage point.

Following the 2007-2008 financial crises, inflation shot to 9% in the middle of 2008 due to high global food and energy prices. In response, the Central Bank tightened the monetary policy stance subsequently increasing the appreciation of the peso. Further the Central Bank intervened in the currency market given the evidence then that the real exchange rate diverted from its long run equilibrium level. In early 2009, the monetary policy rate was reduced aggressively consequently reaching the lower bound. To ease monetary policy further, a non-conventional stimulus was implemented. In particular, the

Central Bank offered a fixed interest rate and six month repos (*the Facilidad de Liquidez a Plazo*, or FLAP) (Carriere-Swallow and Garcia-Silva, 2013). Following the recovery from the crisis, the monetary and fiscal stimuli were withdrawn in 2010.

#### **4.6.2 Results of the Forward looking Taylor rule.**

The estimated Forward looking Taylor rule for Chile suggests that expected inflation and the U.S. interest determined the interest rate (table 15). For instance, other things being held equal, an increase in expected inflation of about 1 per cent causes an increase in the interest rate of about 0.43 basis points. Similar to Botswana, the coefficient of the expected inflation was however less than unity and did not satisfy the Taylor principle. This tends to suggest that the central bank policy was inflationary during the period under review.

On the other hand a 1 per cent increase in the U.S. interest rate leads to an increase in the central bank rate of about 0.56 basis points other things being equal. The coefficient of the interest rate smoothing was 0.30. The estimated equation explains about 73 per cent of the variation in the central bank policy rule. The J–statistic did not reject that the overidentifying restrictions were satisfied. Including the exchange rate in the Forward looking Taylor rule confirmed the significance of the U.S. interest rate in the central bank policy rule of Chile (table 16). Though appearing with the correct negative sign, the exchange rate was insignificant.

### **4.7 Namibia**

#### **4.7.1 Monetary policy in Namibia**

After the First World War, the financial system of Namibia was deeply integrated into that of South Africa<sup>39</sup>. In 1961, the South African Reserve Bank (SARB) opened a branch in the Namibian capital Windhoek. The functions of the latter were restricted to the issuance of South African currency, administration of exchange controls and provision of banking and clearing services to commercial banks (Mushendami, 2010). The Bank of Namibia was created in 1990, following the attainment of the country's political independence, with the exchange rate subsequently pegged to the South African Rand under the Common Monetary Area (CMA).

Accordingly the monetary policy of Namibia is to maintain fixed exchange rate parity between to the South African Rand<sup>40</sup>. Tjirongo (1995) suggests that monetary policy arrangement in Namibia is similar to a currency board given the fact that it requires that the issuance of domestic currency (Namibia Dollar<sup>41</sup>) to be supported by foreign assets. Furthermore, the monetization of the fiscal deficits is not allowed. Unlike the conventional currency board a central bank oversees the monetary system in Namibia. The former performs the normal central banking functions using the repo as the primary instrument of monetary policy. The Bank of Namibia uses the repo rate as the primary instrument of monetary policy. The Bank of Namibia adjusts the repo rate in line with South African Reserve Bank (SARB) monetary policy stance, and also taking into account the level of international reserves (Bank of Namibia, 2008).

Notwithstanding the above, the Bank of Namibia kept the central bank repo rate variant from the repo rate of South Africa since 1999. Other market operations available at the Bank of Namibia include the call account, the seven-day repurchase transactions and the Bank of Namibia bills. The call account is used for banking institutions to place funds with the Bank of Namibia at an interest rate which varies. The meagreness of government securities, led to the introduction of the Bank of Namibia bills in April 2007. The bills have been issued every after two weeks predominantly to assist banking institutions meet their statutory liquidity requirements.

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<sup>39</sup> Namibia was a colony of South Africa until 1990.

<sup>40</sup> The South African Rand is still a legal tender together with the Namibia Dollar.

<sup>41</sup> The Namibia Dollar was first issued in 1993.

In July 2008, the Bank of Namibia introduced the seven day refinancing facility which is based on the repurchase agreements (repos) as the main tool of accommodating banking institutions at an interest rate equivalent to the prevailing central bank rate (repo). The central bank can use the repo facility to either increase short-term liquidity or create a shortage. The latter may occur when the central bank expects that further injection of liquidity might create unnecessary capital outflow and consequently put undue pressure on the level of the official reserves. The financial crisis of 2007-2008 had minimal direct impact on the Namibian financial sector, partially attributed to conservative lending practices of commercial banks which limited their exposure to the crisis. To mitigate the spill over effects of the financial crisis however, the government undertook counter-cyclical fiscal expenditure programmes in particular capital investment in economic and social infrastructure.

#### **4.7.2 Results of the Forward looking Taylor rule.**

The estimated Forward looking Taylor rule for Namibia suggests that the interest rate responds to changes in the South African interest rate and the U.S. interest rate (table 15). For instance an increase in the South African interest rate of about 1 per cent causes a hike in the central bank policy rate of about 0.83 basis points which is close to one. The significance of the South African interest rate was expected and could be explained by the free capital mobility between Namibia and South Africa. On the other hand an increase in the U.S. interest rate of 1 per cent leads to an increase in the central bank policy rate of about 0.04 basis points. The coefficient of the expected output gap was statistically insignificant, while the expected inflation appeared with a wrong sign.

The explanatory power was very high at 0.95 per cent. Including the South African exchange rate in the estimated Forward looking Taylor rule confirms the significance of the U.S. interest rate in the central bank reaction function of Namibia (table 16). Expected inflation and the South African exchange rate were significant, despite the sign of the former which remained wrong. The expected output gap was still insignificant. The J-statistics did not reject the hypothesis that the overidentifying restrictions were satisfied.

The significance of the U.S. interest rate tends to suggest that the central bank of Namibia took into account other factors when making monetary policy decisions. Thus the results tend to challenge the impossible trinity theory which suggests that a country with a fixed exchange cannot have independent monetary policy.

## **4.8 Peru**

### **4.8.1 Monetary policy in Peru**

The persistent high inflation as well as macroeconomic imbalances during the 1970s and 1980s culminated in Peruvian households holding foreign currency (financial dollarization) as a store of value. In August 1985, the Peruvian authorities implemented measures which were intended to enforce the conversion of foreign assets into local assets (Hardy and Pazabasioglu, 2006). Consequently, dollarization dropped sharply by almost 80 per cent to 12 per cent in 1987 (Bofinger, 2009).

The restrictions on holding foreign currency however, brought macroeconomic instability such as low levels of financial intermediation, fall in the incomes of residents when measured in foreign currency, capital flight and loss of credibility (Bofinger, 2009). Consequently, authorities lifted the restrictions of holding foreign currency in 1988 and thus the dollarization re-emerged during the early 1990s. As a policy response, the Peruvian authorities introduced a number of financial, monetary and fiscal reforms to address the problem which brought restored macroeconomic stability (Rossini et al, 2011).

In response to the disinflation, the monetary policy of Peru followed a monetary targeting framework from 1991 to 2001, without any obligation to either the exchange rate or interest rate (Bofinger, 2009). The Central Bank of Peru (BCR) approved the adoption of an *explicit inflation targeting* (IT) framework on the 24 January 2002. The annual inflation

target was set at 2.5 per cent which was reduced to 2 per cent at the beginning of 2007. The tolerance margin range has been set at 1 per cent. The reduction in the inflation target was done in attempt to reduce the vulnerabilities ascribed to the dollarization and hence to reinforce the confidence in the domestic currency. Consequently, the average inflation has been 2.7 per cent during the period under review.

The targeted inflation of 2 per cent is one of the lowest in Latin America (Armas and Grippa, 2005). The BCR changes the reference short-term interest rate (the benchmark for the overnight interbank rates) to carry out monetary policy. Moreover, the central bank attempts to align the money market's interbank interest rate to the reference level. In particular the central bank carries out direct repos and rediscounts and provides an overnight deposit facility. Furthermore, the BCR injects or withdraws liquidity in the system through open market operations and foreign currency swaps. In 2007, currency swaps were introduced to inject domestic currency or withdraw foreign exchange particularly US dollars (Central Bank of Peru, 2009).

Foreign exchange market interventions in Peru serve as a management tool to minimise extreme exchange rate fluctuations without announcing a predetermined path of level (Central Bank of Peru, 2008). Thus, the Peruvian monetary policy framework can be better described as an adjusted inflation targeting comprising of three pillars: Inflation targeting, liquidity management and dollarization risk control. A peculiar characteristic of Peruvian inflation targeting is the dollarized risk control, which is the main reason for including the financial stability (direct purchases and sales of foreign exchange) into the monetary policy framework.

In addition, it supplies the market with hedging assets through the issuance of exchange rate indexed securities (CDRs), (Armas and Grippa, 2005). During the financial crisis of 2007 to 2008 for instance, the BCR intervened three times in the foreign exchange market, firstly before the fall of the Lehman Brothers, secondly after the collapse of the Lehman and third following the announcement of the second quantitative easing of the

U.S. Federal Reserve Bank (QE2). In particular, the BCR purchased U.S.dollars before the collapse of the Lehman brothers, during the announcement of the fall and during the implementation of the QE2. Similarly, it sold U.S. dollars to the market during the last quarter of 2009, when the crisis was intense (Rossini et al, 2011).

In addition, BCR uses the reserve requirements as an instrument of monetary policy. The BCR makes a distinction between the marginal reserve requirements and legal reserve requirements, whereby only the former is compensated. The central bank mandates commercial banks to hold a higher level of international reserves. In the first quarter of 2008 for instance, following a massive inflow of capital, the BCR increased the domestic and foreign currency reserve requirements and instrumented other measures to discourage non-resident investors from holding instruments issued by the central bank. As a result, the interest rates on the marginal reserve requirements for the domestic currency were increased from 6 to 25 per cent, while reserve requirements on foreign currency were raised from 30 to 49 per cent.

Reserve requirements on deposits of non-residents were raised to 120 per cent. In addition, the central bank imposed a 4 per cent fee on sales or purchases of the central bank papers to foreign participants, i.e. (any participant other than local financial institutions). Subsequent to the quantitative easing undertaken by developed countries and its concomitant effects of increasing capital inflows in the second part of 2010, the BCR raised reserve requirements again (Rossini et al. 2011). This time reserve requirements in foreign currency were raised to 55 per cent.

Besides, dollarization has an impact on the design of the inflation forecasting model. The projection model comprises of four elements: a Phillips curve, a monetary policy rule, an investment-savings curve and an exchange rate equation (Bofinger, 2009). Notably the IS curve includes a US dollar interest rate to take account of dollarization, i.e. (to accommodate the fact that foreign interest rate variations affect the domestic demand decisions. The exchange rate equation comprises of an inertia term to take into account



the central bank's tendency to intervene in the exchange rate. Dollarization also implies that the inflation targeting has an escape clause to fight extreme exchange rate depreciation. Accordingly, the interbank interest rate is permitted to abandon the predetermined band in an event of severe depreciation or speculative attack (Amas and Grippa, 2005).

#### **4.8.2 Results of the Forward looking Taylor rule**

All the variables in the central bank reaction function of Peru displayed the expected signs, however the expected output gap was insignificant. Accordingly, the central bank interest rule responds to changes in the U.S. interest rate, expected inflation and the past interest rate (table 15). Other things being held equal, a 1 per cent increase in expected inflation is expected to lead to a rise in the central bank rate of about 0.53 basis points. Similarly, a 1 per cent increase in the U.S. interest rate causes an increase in the central bank rate of about 0.56 basis points. These results were similar to those of Botswana and Chile. The explanatory power for the estimated central bank reaction function was very high, with the Adjusted R-squared of 0.89 per cent. The hypothesis that the model was overidentified could not be rejected. The results of the estimated Forward looking Taylor rule which include the exchange rate confirmed that the central policy rate responded to changes in the U.S. interest rates, expected inflation, the expected output gap and the exchange rate (table16). The latter tends to be overstated.

### **4.9 Philippines**

#### **4.9.1 Monetary policy in Philippines**

In the 1980s, the Central Bank of the Philippines (BSP) used direct methods of monetary policy such as setting interest rates on bank deposits and loans. This policy was similar to Botswana's policy during the same period. The interest rate set by the central bank

was considered low and thus contributed to the financial chaos then. Thus the regulatory authorities embarked on a comprehensive financial sector reform.

The reforms concentrated on liberalising the foreign exchange regulations and included: (1) Investors were given the liberty to buy foreign currency up to \$1 million a year from the local banking institutions and invest it abroad without the approval of the central bank. (2) Limits on the repatriation of capital or remittances were abolished: (3) foreign banks were allowed to extend foreign currency denominated short term credit to domestic borrowers without seeking the approval of the central bank: (4) Domestic commercial banks were also allowed to issue both short and long-term foreign currency denominated loans without obtaining the approval of the central bank. (5) Interest rates were liberalised and deregulated in 1981-1983. The reforms were not implemented successfully due to political and economic crises until the latter part of 1980s.

Following the financial sector reforms, there were large interest rate margins between the borrowing and lending rates. In addition interest rates on time deposits were variant. For example interest rates on six month deposits differed by 1 per centage point to the interest rate offered on twelve month deposits. During the same period the central bank used government securities as the primary monetary policy instrument. At the end of the of the debt crisis in 1983, the exchange rate was floated in October 1984 (Poon, 2010). In addition monetary aggregate (M3) was adopted as a signal of the monetary policy stance as well as a means to achieve price stability. This approach assumed the existence of a stable and predictable relationship between money, output, and inflation. Moreover, monetary targeting assumed that the central bank could control inflation by determining the level of money supply. On the contrary, Bayangos (2000) observes that the rise in M3 in 1993-1995 did not transmit to higher inflation in the Philippine.

Similarly, Poon (2010) contend that the relatively high growth of M3 of about 40 per cent in the early part of 1995 did not cause an increase in inflation even after 8 to 12 months. In 1995, a new approach which emphasised price stability rather than a rigid observance

of monetary aggregate targets was adopted. Under the new framework, the BSP was allowed to exceed the monetary targets in instances where the actual inflation rate is kept within program levels. Moreover, policymakers began scrutinizing a larger set of economic variables such as changes in key interest rates, demand and supply factors, the exchange rate, domestic credit, among other variables before taking an appropriate monetary policy position.

Following the crisis of 1997, the peso depreciated by more than 50 per cent. The subsequent rise in interest rate did not however make a significant impact to mitigate the impact of the depreciation. Consequently, monetary targeting was perceived as a less reliable tool of monetary policy in the Philippines. The Monetary Board of the BSP approved in principle the migration to inflation targeting as the new framework for carrying out monetary policy on 24 January 2000. Similar to other frameworks, the primary focus of the IT was to achieve price stability as the final objective of monetary policy.

The central bank together with the government (through an inter-agency body) announces an explicit target for inflation to be achieved over a prescribed time period. In terms of assessment, the central bank compares the actual headline inflation against inflation forecasts. The BSP uses a host of monetary policy instruments at its disposal to achieve the inflation target such as adjustments in the BSP's key policy interest rates, rediscounting and reserve requirements. The BSP presents reports which among other things explain the policy decisions and provide an assessment of the inflation environment and outlook. Also, the central bank is mandated to explain to the public and market should it fail to meet the inflation target as well as measures to steer inflation towards the target level.

At the time of adopting inflation targeting, the target inflation was defined as a range with one per centage point interval. However, in 2008 the target was redefined to a point target. Accordingly, the point target for 2008 was set at 4 per cent with a tolerance level

of one per cent both sides. For 2009 onwards the target was set at 3.5 per cent with a tolerance level of one per cent on both sides as well. In 2008, the central bank policy rate was raised by 100 basis points over a period of three month (June to August). This was done to mitigate the pressure of extra ordinary increases on inflation. However, by the end of December 2008, there was a downward shift in the inflation expectation on account of a host of factors such as easing commodity prices and a slowdown in expected economy activity. These developments laid the ground for easing monetary policy to support growth and also help the country to mitigate the effects of the financial crises (Guinigundo, 2010).

#### **4.9.3 Results of the Forward looking Taylor rule.**

The estimated central bank reaction function of the Philippines suggests that the interest rate was determined positively by expected inflation, the expected output gap and interest rate in the previous period. Holding other things equal, a one per cent increase in expected inflation was expected to lead to a 0.27 basis points increase in the central bank policy interest rate. Similar to other countries, the estimated inflation coefficient was less than unity which is recommended by the Taylor Principle. The interest rate smoothing parameter was estimated at 0.34 per cent. The Forward looking Taylor rule augmented for the exchange rate on the other hand shows that the U.S.interest rates, expected inflation, expected output gap were positively correlated with the central bank interest rate in the Philippine, and negatively correlated with the exchange rate.

### **4.10 South Africa**

#### **4.10.1 Monetary policy in South Africa**

Monetary policy regimes in South Africa since the 1960s can be classified under three broad strands. The first which ceased in the early 1980s was the liquid asset ratio-based characterised by quantitative controls on interest rates and credit. Following the

recommendations of the De Kock Commission Reports (1978, 1985) a number of reforms were introduced from the early 1980s which subsequently culminated into the introduction of a cash reserve-based system in the middle of 1985 (Gidlow, 1995). SARB adopted inflation targeting in 2000 to enhance policy transparency, accountability and predictability.

Presently, the inflation target aims to achieve a rate of increase in the overall consumer price index, excluding the mortgage interest cost (the so-called CPIX), of between 3 and 6 per cent per year. Initially, the mandate of setting the target range was the prerogative of the Ministry of Finance. However, it is presently set by the National Treasury (a department of the Ministry of Finance), after consultation with the SARB. The final government decision is reached at Cabinet level. In 2001, the Inflation Targeting Technical Committee (ITTC) was established, with representatives from the National Treasury and SARB. The target for inflation has been modified several times. For instance in February 2000, the target for the calendar year 2002 was set as an average rate of increase in CPIX of 3-6 per cent per annum. This was extended every October of the following year to cover for 2003. The target for 2004 and 2005 was initially scaled down to 3-5 per cent for 2004 and 2005, but was subsequently raised up to 3-6 per cent, to mitigate exogenous shocks.

A diverse number of changes were implemented from September 2001 and May 2005 to address a poorly functioning money market, which was due to a significant domination of a few large banks. These changes proved effective given that the participation in the market increased. In September 2005, the spread between the repo rate and interbank call rate was changed with a 100 basis point reduction in the repo rate. Presently, the repo rate is fixed to get rid of any vagueness in the SARB's policy. Moreover, daily auctions have been substituted with weekly repurchase auctions with a seven day maturity. To assist in tendering, an estimate of the average daily market liquidity requirement is announced before the auction. The latter began in May 2005. Moreover, the SARB can conduct further auctions to accommodate liquidity requirements as well as

to stabilize the interbank rates. In November 2003, the target range was changed from an average over the calendar to a continuous target of 3-6 per cent beyond 2006. This was done to mitigate potential interest rate volatility that might arise from a short target horizon.

#### **4.10.2 Results of the Forward looking Taylor rule**

The estimated Taylor rule for South Africa states that the central bank policy rate was determined by the expected inflation and past values of the central bank interest rate (table 15). For instance other things remaining unchanged, a 1 per cent increase in the expected inflation leads to an increase in the bank rate of about 0.47 basis points. The expected output gap and the U.S. interest rate were insignificant despite displaying the expected positive relationship. The interest rate smoothing parameter was very small estimated at 0.18 basis points. The equation seems to explain about 80 per cent of the variations in the dependent variable (central bank interest rate). The results were confirmed by estimating an equation which includes the exchange rate in the Forward looking Taylor rule. The exchange rate appeared with the correct negative sign however it was insignificant (table16).

### **4.11 Thailand**

#### **4.11.1 Monetary policy in Thailand**

Central banking in Thailand dates back to the 1942's when the Bank of Thailand (BOT) was founded. Immediately after establishment, the BOT followed exchange rate targeting regime. In particular, from 1942 to 1984, the Baht was pegged to a basket of currencies, but was later replaced by the U.S.dollar in 1984. The BOT adopted a monetary targeting regime in 1997 in response to the pressure from the IMF. Thailand was under the IMF assistance program following the Asian financial crisis of 1997. The monetary policy objective then was to ensure macroeconomic stability and also to restore the confidence lost due to the failure of the fixed rate regime.

The BOT targeted domestic money supply, despite for a very short period and hence was abandoned. Following the end of the IMF program in May 2000, BOT launched the Inflation Targeting framework. The BOT targets the core inflation (excluding energy and fresh food). The target range is a quarterly average for inflation of between 0.5 to 3.0 per cent. The target is set annually, first proposed by the BOT, with the concurrence of the Minister and endorsement of cabinet.

Unlike other countries, Thailand's inflation targeting has no escape clause which protects the central bank in the event of energy or supply shocks. By targeting core inflation rather than headline inflation, the BOT puts emphasis on demand factors which it can influence. In 2005 and 2008 during high international oil price shocks, the BOT was assisted by the government in meeting its inflation targets. For instance, the Ministry of Commerce gave subsidies for energy and transport, and also put price controls on producers by way of decrees and monitoring. In 2009, an additional six measures were introduced to reduce the cost of living, which also had the objective of mitigating the impact of the crisis.

#### **4.11.2 Results of the Forward looking Taylor rule**

The Forward looking Taylor rule for Thailand suggests that the central bank interest rate responded to the U.S. interest rate, expected inflation, past interest rate and the expected output gap (table 15). Other things being held unchanged, a one per cent rise in the U.S. interest rate led to an increase in the Thai interest rate amounting to 0.11 basis points. Similarly, a one per cent increase in the expected inflation brings about a 0.11 basis points rise in the central bank policy rate. The expected output gap was negative suggesting that the interest rate was pro cyclical in Thailand. The smoothing parameter was estimated at 0.76 per cent. The estimated equation explains about 0.85 per cent of the changes in the interest rate in Thailand, as given by the adjusted R squared value. The results from the Forward looking Taylor rule including the exchange

rate affirmed the significance of the U.S. interest rate in monetary policy function rule of Thailand (table16).

#### **4.12 Conclusion**

This chapter examines the hypothesis that developing countries tend to respond to changes in the international interest rates particularly the U.S. interest rate in setting their domestic interest rate. The chapter uses eight developing countries to address the research question. Among the selected countries 6 were inflation targeters. The empirical results from the Forward looking Taylor rule suggests that Botswana, Chile, Namibia, Peru, the Philippines and Thailand reacted to changes in the U.S. interest rate in setting their nominal interest rate. The only exception was South Africa.

The empirical results show further that the coefficient of the expected inflation was significant in Botswana, Chile, Namibia<sup>42</sup>, Peru, the Philippines, South Africa and Thailand but less than unity, thus violating the Taylor principle. This suggests that monetary policy in these countries was accommodative during the period under review. Hofman and Bogdanova (2012) attribute the accommodative bias of developing economies to resistance to the concomitant capital flows and exchange rate movements. For instance developing countries might tend to keep interest rates low to mitigate against the appreciation of the exchange rate. Keeping the interest rates lower than the prescribed Taylor's principle may partially explain the high inflation experience in developing countries.

Furthermore, the coefficient on the expected output gap was insignificant in countries reviewed except in Brazil, Peru and the Philippines. This can be accounted by the fact that developing countries tend to respond more to supply shocks rather than demand shocks when changing the bank rate. The interest rate parameter ranged between 0.7 per cent to 0.9 per cent. The J–statistic did not reject that the overidentifying restrictions were satisfied in all the estimated monetary policy reaction functions. The result from the

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<sup>42</sup> The expected inflation coefficient however showed a wrong sign.



Forward looking Taylor rule augmented with the exchange rate confirms the results from the baseline estimation. Based on these results I conclude that developing countries tend to respond to past interest rates, expected inflation and the US interest rates. A regional comparison shows that changes in the U.S.interest rate had more profound effects on the interest rates in Latin American countries.

## **Chapter 5 Conclusions, contribution and further research.**

This thesis contributes to the theoretical and empirical literature on monetary policy rules as follows. Firstly, it examines the implications of interest smoothing on the persistence of a monetary policy and technology shock. Secondly, it evaluates the performance of monetary policy rule (targeting or instrument rule) in the presence of a cost push shock. Thirdly, it investigates whether developing economies react to international interest rate(s) when setting their interest rates?

The first objective is addressed in chapter 2, which attempts to examine the implication of interest rate smoothing on the persistence and transmission of a technology and monetary policy shock. Monetary policy is viewed as effective when its persistence on inflation is short lived in contrast to long live persistence. The intuition is that the central bank is able to achieve its objective of fighting inflation in a very short time when the persistence is short lived. On the contrary when the persistence of inflation is long lived, the central bank is only able to achieve its objectives after a long period of time and thus considered as ineffective (Gerlach and Tillmann, 2010).

The chapter is based on Gali (2008) closed economy model. I extend the model and therefore contribute to the model by introducing two monetary policy rules, namely the Taylor rule with lagged interest rate and the backward looking Taylor rule. Using the impulse response of inflation, I show that the Taylor rule with lagged interest rate and backward looking Taylor rule (interest rate smoothing) protracts the persistence of a monetary policy shock, while it truncates the persistence of a technological innovation. The persistence due to a monetary shock from the Taylor rule is however shorter, while that from a technology shock is longer.

Thus, Taylor rule is considered superior to the Taylor rule with lagged interest rule or the backward looking Taylor rule when the economy is hit by a monetary policy shock. On the contrary, the Taylor rule with lagged interest rate and the backward looking Taylor rule is considered superior to the Taylor rule when the economy is faced with a

technology shock. These results tend to suggest that a policy maker faces a trade off as to which policy rule to select.

The second objective is addressed in chapter 3, which compares the performance of targeting rules and instrument rules given three shocks, technology shock, foreign output shock and a cost push shock. The chapter is based on Galí (2008) small open economy model. I extend the model and hence contribute to literature in three ways. Firstly, I include a cost push shock and a foreign output shock. Secondly, I model the DIT, and CIT rules as in Galí and Monacelli (2002). Thirdly, I include the forward looking Taylor rules as in Clarida, Galí and Gertler (1998).

Using the impulse response function as well as the volatility of the output gap and domestic inflation as the yardstick of the evaluation, I show that the results of Galí (2008) that the DIT policy is superior in the presence of a technology shock can be extended to a foreign output shock. That is DIT is superior when a foreign output shock hits the economy as well. The Taylor rule is superior to the CGG(+1) and CGG(+4). In the presence of a cost push shock, there is no single policy which stabilises both the output gap and domestic inflation.

The DIT is only superior in stabilizing the domestic inflation while the CGG(+1) minimising the volatilities of the output gap the most. The CGG(+4) tend to increase the volatility of the output gap and domestic inflation and thus is ranked as the most inferior policy rule given this model and calibration. The intuition of these results is that the central bank faces a policy dilemma as to which policy rules is superior in terms of stabilising both the output gap and domestic inflation when the economy is hit by a cost push shock. When the shock is caused by a technology shock or foreign output, the policy maker would prefer the DIT rule.

However, if the shock is caused by a cost push factor, the policy maker would prefer the DIT rule to stabilise the domestic inflation or the CGG (+1) to minimise the volatilities in the output gap. In practise however policy makers cannot alter policy rules with each

shock hitting the economy and hence faces a policy dilemma in particular when faced with a cost push shock.

Chapter four answers the third objective and empirically test whether developing countries respond to international interest rates in setting their policy rates or observe the Taylor rule. The chapter draws mainly from Clarida, Galí and Gertler (1998), Calvo and Reinhart (2001 and 2002), Filosa (2001), Corbo (2002), Frankel et al. (2004) and Boamah (2012). These studies show that emerging market economies respond to other factors such as the exchange rate in setting their interest rate policy in addition to inflation. This is attributed to the fear of floating which might be caused by among other things: lack of credibility, exchange rate path through to inflation and foreign currency liabilities which may prevent developing countries from undertaking independent monetary policies. Frankel et al (2004) argues for example that even developing countries with fully flexible exchange rate tend to import price stability from developed countries similar to countries whose exchange rates are fixed.

My first contribution to literature in this chapter is that I examine the interest rate setting behaviour of central banks in three regions (Latin America, East Asia and Southern Africa, using data from 1999 to 2012. I build on Forward looking Taylor rule proposed by Clarida, Galí and Gertler (1998). However, I make two modifications to their rule and thus contribute to literature as follows: First I replace the output with the expected output as in Javanovic and Petreski (2012). Second I include the U.S. interest rate, to test the claim by Frankel et al (2004) that interest rates in developing countries with flexible exchange rates might sometimes be more responsive to international interest rates in addition to domestic economic considerations.

I show that developing countries respond to past interest rates, expected inflation and international interest rates (US interest rate) when setting their interest rates. The coefficient of the expected inflation is less than unity in all countries suggesting that developing countries tend to accommodate inflation. These results are similar to Corbo's for Latin American countries. A distinct finding of this chapter is the significance of the

US interest rate in the monetary policy rules of most countries, when they are all inflation targeters.

#### Limitations and further research

This thesis contributes to the theoretical and empirical literature on monetary policy rules by firstly examining the implications of interest smoothing on the persistence of a monetary policy and technology shock. Secondly, it evaluates the performance of monetary policy rule (targeting or instrument rule) in the presence of a cost push shock. Thirdly it investigates whether developing economies react to international interest rate(s) when setting their interest rates?

There a number of constrains which the thesis did not address. In the second and third chapters, the extant research on the monetary policy tends to use welfare based measures of analysis to compare and rank various monetary policies. Moreover, since the 2007 financial crisis most central banks have expanded their mandates to include financial stability in addition to price stability. Thus it is recommended for future research to include welfare based measures and include financial stability objectives in the monetary policy rules of the central bank. In addition, chapter four could be expanded by including monetary aggregates to examine its significance in the monetary policy rules of developing countries.

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**Table 6 Data Statistics.**

Botswana				
	$\pi$	$i$	$y$	$e$
Mean	8.44	13.17	8.63	0.16
Median	7.79	14.25	8.67	0.16
Max	14.67	15.50	8.91	0.23
Min	5.63	9.50	8.26	0.00
STD. Dev	2.23	2.11	0.18	0.05
Obser	56	56	56	56

Brazil				
	$\pi$	$i$	$y$	$e$
Mean	6.50	14.62	4.61	0.47
Median	6.20	14.75	4.62	0.48
Max	16.85	26.50	4.75	0.64
Min	0.00	0.00	4.41	0.26
STD. Dev	2.97	4.93	0.10	0.10
Obser	52	52	52	52

Chile				
	$\pi$	$i$	$y$	$e$
Mean	3.28	4.44	4.53	0.00
Median	3.10	4.89	4.57	0.00
Max	9.33	13.08	4.74	0.00
Min	-1.86	0.48	4.32	0.00
STD. Dev	2.17	2.60	0.11	0.00
Obser	52	52	52	52

Namibia				
	$\pi$	$i$	$y$	$e$
Mean	7.14	9.35	9.28	0.14
Median	6.95	9.25	9.30	0.14
Max	13.60	16.00	9.59	0.17
Min	1.30	6.00	9.00	0.08
STD. Dev	2.98	2.4	0.18	0.02
Obser	52	52	52	52

Peru				
	$\pi$	$i$	$y$	$e$
Mean	2.65	5.65	4.67	0.32
Median	2.39	5.02	4.67	0.31
Max	6.64	17.80	4.99	0.39
Min	-1.01	2.05	4.33	0.27
STD. Dev	1.63	3.74	0.22	0.03
Obser	52	52	52	52

Philippine				
	$\pi$	$i$	$y$	$e$
Mean	4.16	5.40	4.51	0.02
Median	3.86	4.58	4.55	0.02
Max	10.28	13.80	4.75	0.02
Min	-1.01	3.11	4.15	0.02
STD. Dev	2.24	2.00	0.16	0.00
Obser	52	52	52	52

South Africa				
	$\pi$	$i$	$y$	$e$
Mean	5.87	8.83	4.79	0.13
Median	5.67	8.00	4.60	0.13
Max	13.42	13.50	14.49	0.17
Min	0.43	5.00	4.48	0.08
STD. Dev	2.93	2.60	1.37	0.01
Obser	52	52	52	52

Thailand				
	$\pi$	$i$	$y$	$e$
Mean	2.66	3.52	6.88	0.03
Median	2.60	3.50	6.92	0.03
Max	7.50	6.50	7.16	0.03
Min	-2.79	1.75	6.58	0.02
STD. Dev	1.97	1.15	0.16	0.00
Obser	52	52	52	52

**Table 7 Unit Root Tests: Botswana**

Variable	ADF <sup>43</sup>	PP <sup>44</sup>	ADF-GLS <sup>45</sup>	Decision
Interest rate	>0.10 <sup>46</sup>	>0.10	>0.10	Non-stationary
Interest rate-gap	<0.05	<0.10	<0.01	Stationary
Inflation	>0.01	>0.05	>0.10	Non-stationary
Inflation-gap	<0.01	<0.10	<0.01	Stationary
Output	>0.10	>0.10	>0.10	Non- stationary
Output gap	<0.01	<0.01	<0.01	Stationary
Exchange rate	>0.10	>0.10	>0.10	Non-stationary
Exchange rate-gap	<0.10	<0.10	<0.05	Stationary
US interest rate	>0.10	>0.10	<0.10	Non- stationary
US interest rate-gap	<0.01	<0.10	<0.01	Stationary

**Table 8 Unit Root Tests: Brazil.**

Variable	ADF	PP	ADF-GLS	Decision
Interest rate	>0.10	>0.10	>0.10	Non-stationary
Interest rate-gap	<0.01	<0.10	<0.01	Stationary
Inflation	>0.10	>0.10	>0.10	Non-stationary
Inflation-gap	<0.01	>0.10	<0.01	Stationary
Output	>0.10	>0.10	>0.10	Non- stationary
Output gap	<0.01	<0.05	<0.01	Stationary
Exchange rate	>0.10	>0.10	>0.10	Non-stationary
Exchange rate-gap	<0.05	<0.10	<0.05	Stationary

<sup>43</sup> Augmented Dickey-Fuller.(The Akaike Information Criterion (AIC) with a maximum number of ten lags was used in the test.

<sup>44</sup> Phillips-Perron

<sup>45</sup> Dickey-Fuller Test with GLS Detrending.

<sup>46</sup> P-Values.

**Table 9 Unit Root Tests: Chile.**

Variable	ADF	PP	ADF-GLS	Decision
Interest rate	<0.05	<0.01	>0.10	Probably-stationary
Interest rate-gap	<0.05	<0.01	<0.10	Stationary
Inflation	<0.01	>0.10	>0.10	Non-stationary
Inflation-gap	<0.01	<0.10	<0.01	Stationary
Output	>0.10	>0.10	>0.10	Non- stationary
Output gap	<0.05	<0.01	<0.01	Stationary
Exchange rate	>0.10	>0.10	>0.10	Non-stationary
Exchange rate-gap	<0.05	<0.05	<0.05	Stationary

**Table 10 Unit Root Test: Namibia.**

Variable	ADF	PP	ADF-GLS	Decision
Interest rate	>0.10	>0.10	>0.10	Non-stationary
Interest rate-gap	<0.05	<0.05	<0.05	Stationary
SA Interest rate	>0.10	>0.10	>0.10	Non-stationary
SA Interest rate-gap	<0.05	<0.10	<0.05	Stationary
Inflation	<0.10	>0.10	>0.10	Non-stationary
Inflation-gap	<0.05	<0.10	<0.01	Stationary
Output	>0.10	>0.10	>0.10	Non- stationary
Output gap	<0.01	<0.01	<0.01	Stationary
SA Exchange rate	>0.10	>0.10	>0.10	Non-stationary
SA Exchange rate-gap	<0.10	<0.10	<0.05	Stationary



**Table 11 Unit Root Tests: Peru.**

<b>Variable</b>	<b>ADF</b>	<b>PP</b>	<b>ADF-GLS</b>	<b>Decision</b>
Interest rate	>0.10	>0.10	>0.10	Probably-stationary
Interest rate-gap	<0.01	<0.10	<0.05	Stationary
Inflation	<0.05	<0.01	<0.05	Stationary
Inflation-gap	<0.01	<0.10	<0.01	Stationary
Output	>0.10	>0.10	>0.10	Non- stationary
Output gap	<0.01	<0.01	<0.01	Stationary
Exchange rate	>0.10	>0.10	>0.10	Non-stationary
Exchange rate-gap	<0.05	<0.05	<0.01	Stationary

**Table 12 Unit Root Tests: Philippine.**

<b>Variable</b>	<b>ADF</b>	<b>PP</b>	<b>ADF-GLS</b>	<b>Decision</b>
Interest rate	>0.10	>0.10	>0.10	Non-stationary
Interest rate-gap	<0.01	<0.01	<0.01	Stationary
Inflation	<0.01	<0.05	<0.05	Stationary
Inflation-gap	<0.01	<0.05	<0.05	Stationary
Output	>0.10	>0.10	>0.10	Non- stationary
Output gap	<0.01	<0.01	<0.01	Stationary
Exchange rate	>0.10	>0.10	>0.10	Non-stationary
Exchange rate-gap	<0.05	<0.05	<0.05	Stationary

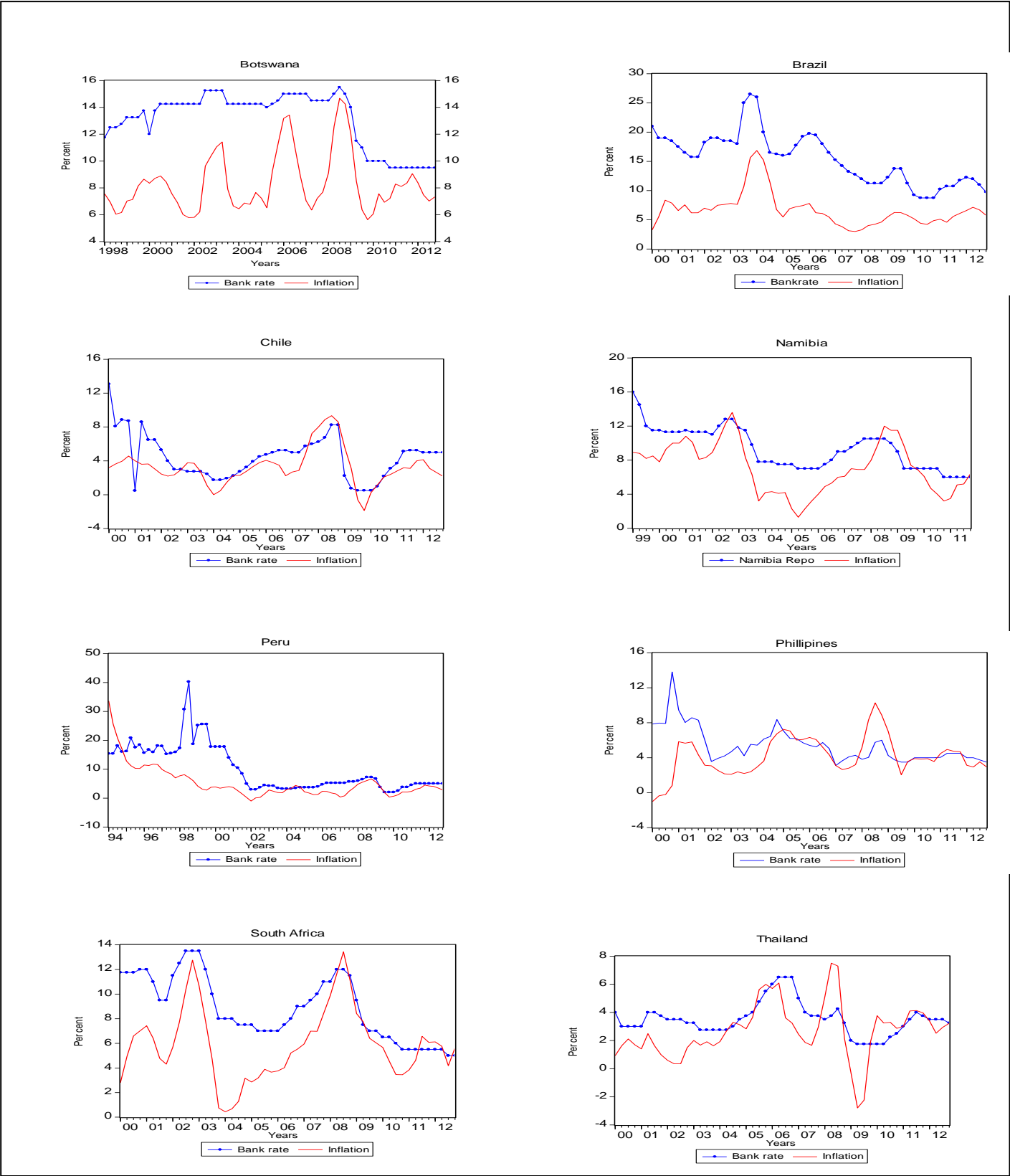
**Table 13 Unit Root Tests: South Africa.**

Variable	ADF	PP	ADF-GLS	Decision
Interest rate	>0.10	>0.10	>0.10	Non-stationary
Interest rate-gap	<0.05	<0.10	<0.05	Stationary
Inflation	>0.10	<0.10	<0.10	Stationary
Inflation-gap	<0.01	<0.05	<0.05	Stationary
Output	>0.10	>0.10	>0.10	Non- stationary
Output gap	<0.01	<0.01	<0.01	Stationary
Exchange rate	>0.10	>0.10	>0.10	Non-stationary
Exchange rate-gap	<0.10	<0.10	<0.05	Stationary

**Table 14 Unit Root Tests: Thailand.**

Variable	ADF	PP	ADF-GLS	Decision
Interest rate	>0.10	>0.10	>0.10	Non-stationary
Interest rate-gap	<0.10	<0.10	<0.01	Stationary
Inflation	<0.01	>0.10	>0.10	Stationary
Inflation-gap	<0.01	<0.10	<0.01	Stationary
Output	>0.10	>0.10	>0.10	Non- stationary
Output gap	<0.01	<0.01	<0.10	Stationary
Exchange rate	>0.10	>0.10	>0.10	Non-stationary
Exchange rate-gap	<0.05	<0.05	<0.01	Stationary

Figure 9    Inflation and Interest Rates (Bank Rate)



**Table 15 Results of the Forward looking Taylor rule.**

Country	$\alpha$	$i_{t-1} > 0.$	$\pi_{t+1} > 0.$	$y_{t+1} > 0.$	US Interest Rate > 0.	SA Interest rate > 0.	Adjusted $R^2$	Adjusted statistic	$p-J$
Botswana	0.64 (-3.26) <sup>47</sup>	0.69 (11.84)	0.07 (3.33)	0.90 (1.28)	0.10 (3.26)	-	0.74	9.15	0.68
Brazil	-0.03 (-0.13)	0.97 (6.61)	-0.03 (-0.17)	30.74 (5.49)	-0.48 (-2.83)	-	0.50	7.14	0.84
Chile	0.13 (2.07)	0.30 (3.01)	0.43 (6.39)	-2.56 (-0.81)	0.56 (4.54)	-	0.73	7.74	0.80
Namibia	-0.07 (-4.23)	0.09 (2.15)	-0.07 (-4.23)	1.19 (1.11)	0.04 (2.30)	0.83 (14.85)	0.95	9.16	0.86
Peru	-1.55 (-7.52)	0.20 (2.09)	0.53 (6.25)	2.72 (1.44)	0.56 (4.95)	-	0.89	9.15	0.68
Philippine	-3.21 (-8.45)	0.34 (4.85)	0.27 (6.23)	0.02 (6.34)	-0.07 (-1.57)	-	0.59	7.86	0.79
South Africa	-0.00 (-0.02)	0.18 (2.33)	0.47 (14.01)	0.28 (1.42)	0.01 (0.17)	-	0.82	8.5	0.74
Thailand	0.05 (1.78)	0.76 (13.92)	0.11 (4.49)	-3.62 (-3.76)	0.11 (4.22)	-	0.85	7.2	0.83

<sup>47</sup> t-statistics.

**Table 16 Results of the Forward looking Taylor rule with the Exchange Rate.**

Country	$\alpha$	$i_{t-1}$	$\pi_{t+1}$	$y_{t+1}$	US Interest Rate	Exchange rate < 0.	Adjusted $R^2$	L statistic	$p-J$	SA Interest rate
Botswana	0.04 (1.95)	0.64 (10.00)	0.10 (4.49)	0.42 (0.53)	0.07 (2.94)	-3.33 (-2.70)	0.79	9.94	0.82	-
Brazil	-0.04 (-0.31)	0.83 (9.26)	0.10 (1.04)	32.15 (5.70)	-0.26 (-2.53)	-11.85 (-4.63)	0.52	8.89	0.88	-
Chile	0.10 (0.73)	0.17 (1.43)	0.55 (4.91)	-6.95 (-1.00)	0.76 (3.43)	-964.05 (-0.50)	0.73	15.5	0.41	-
Namibia	0.01 (0.56)	0.04 (1.25)	-0.04 (-3.08)	1.15 (1.23)	0.05 (2.39)	3.74 (1.58)	0.95	9.16	0.86	0.81 (19.37)
Peru	-0.08 (-2.91)	0.35 (6.07)	0.46 (6.94)	4.59 (4.35)	0.49 (7.41)	-23 (-5.25)	0.89	11.04	0.74	-
Philippine	-2.11 (-5.18)	0.31 (4.65)	0.20 (6.06)	0.02 (5.02)	0.13 (2.26)	-288.87 (-3.03)	0.59	8.82	0.88	-
South Africa	-0.02 (-0.29)	0.29 (5.09)	0.38 (15.87)	0.13 (0.87)	0.03 (0.59)	-3.85 (-0.81)	0.85	10.2	0.80	-
Thailand	0.02 (0.65)	0.64 (11.30)	0.13 (6.4)	-0.79 (-0.57)	0.16 (4.66)	-199.68 (-2.61)	0.84	9.3	0.85	-

